

Heritage's Engineering Series

THIRD EDITION

Subjective Handbook of **Building & Architecture**

*Covers the syllabus prescribed by PSC and
other competitive examinations*



Er. Samyog Shrestha

Subjective Handbook of **Building & Architecture**

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How to use this book ?

The depth of knowledge and reasoning tested by Public Service Commission is immense. It is beyond the scope of any book, however bulky, to cover the limitless possibilities of questions you might have to confront. Without exception, this book does not guarantee that you will ace in your subjective exam. This is the reality check. However, another honest reality is that if you understand how to use this book, you will probably succeed.

Use this book as a friend. Extract ideas, references and connecting links from various sections to use them in each of your answers. Since most questions won't demand direct answers, so what you have understood counts far more than how well you have mugged up. I see the trend that each question is related to one particular sub-section in the syllabus; which calls for the need to get the gist of each sub-section thoroughly so that you can scan quickly from which part the question has been extracted and organize your points that you would want to include. Any relevant and logical elaboration would earn you decent score and improve your odds.

Best of luck!

Er. Samyog Shrestha

लोक सेवा आयोग

नेपाल इन्जिनियरिंग सेवा, सिभिल सम्पूर्ण, बिल्डिङ एण्ड आर्किटेक्चर उपसमूहको राजपत्राङ्कित तृतीय श्रेणी पदका खुला र आन्तरिक प्रतियोगितात्मक लिखित परीक्षाको पाठ्यक्रम
द्वितीय पत्र : बिल्डिङ एण्ड आर्किटेक्चर सम्बन्धी विषय।

Section - A

[30 Marks]

30%

1. **Building Materials and Construction**
- 1.1 Stone masonry: Types of stone used in stone masonry, specifications of stone masonry.
- 1.2 Brick masonry: Classification of bricks, specifications of different types of bricks, testing of bricks, different shapes of bricks.
- 1.3 Hollow Concrete Blocks: Various types of concrete blocks, use of concrete blocks in buildings.
- 1.4 Sand: Requirement of good quality sand, sieve analysis, fineness modules.
- 1.5 Lime: Different types of lime and their uses test of freshness.
- 1.6 Mortar: Types of mortar, specifications, proportion of mortar for various types of masonry works.
- 1.7 Paintings: Types of paints, specification for various types of painting Works.
- 1.8 Water proofing: Water proofing at basement, ground floor and roofs, common water proofing problems in Nepal.
- 1.9 Roofing Systems: Different types of roofing system.
- 1.10 Doors and windows: Different types of doors and windows, door and window details, merits and demerits of metal door and windows.
- 1.11 Walls: Different types of wall system, Load bearing walls, partition walls and curtain walls.
- 1.12 Pre-fabrication: Principles of pre-fabrication, advantages and disadvantages of a pre-fabricated building.
- 1.13 Flooring: Different types of flooring, specification of floorings.
- 1.14 Plastering: Different types of plasters and coating materials.
- 1.15 Formworks: Shoring, underpinning, scaffolding and formworks.
- 1.16 Building Elements: Foundation, super structure, lintel, floors, roofs, sun control devices, parapet, staircase, emergency stairs, elevators and escalators
- 1.17 Building services: water supply and sanitation, electrification, heating and ventilation and air-conditioning.
- 1.18 National Building Code: Hierarchy of building codes and its application, procedure for implementation of building code in Nepal.
- 1.19 Development Control System in municipalities in Nepal
- 1.20 Maintenance and repair of buildings.
- 1.21 Principles of low cost construction techniques.
- 1.22 Current building norms for estimating and costing.

Section - B

[20 Marks]

20%

2. **Structural Design and Analysis**
- 2.1 Design of RCC footings, columns, slabs, beams.
- 2.2 Analysis of structural system in a building.
- 2.3 Design of steel structure.
- 2.4 Design of timber structure.
- 2.5 Design of masonry structure.
- 2.6 Common structural problems in RCC buildings in Nepal.

- 2.7 Requirements of earthquake resistant building construction.
- 2.8 Computer Aided Design (CAD) of building structure.
- 2.9 Mandatory Rule of Thumb in building design.
- 2.10 Non-engineered earthquake resistant building design.

Section - C

[30 Marks]

30 %

3. **Housing and Urban Planning**
- 3.1 Hierarchy of urban settlements.
- 3.2 Types of urban settlements in Nepal.
- 3.3 Base Maps.
- 3.4 Hierarchy of plans.
- 3.5 Principles of land use planning.
- 3.6 Building byelaws.
- 3.7 Periodic plans for local authorities.
- 3.8 Planning legislation of Nepal.
- 3.9 Environmental issues in urban development.
- 3.10 Institutions involved in urban planning and development in Nepal.
- 3.11 Types of urban development programmes in Nepal.
- 3.12 Conservation of heritage sites.
- 3.13 Settlement planning for disaster mitigation.
- 3.14 Municipalities of Nepal and their role in urban development.
- 3.15 Town Development Committees and their role in urban development.
- 3.16 Different types of housing.
- 3.17 Principles of housing design.
- 3.18 Different models of land development.
- 3.19 Squatter and slums.
- 3.20 Private housing development.
- 3.21 Rural housing, housing development programmes in Nepal.
- 3.22 Prospects of apartments and group housing in Nepal.

Section - D

[20 Marks]

20%

4. **Architecture**
- 4.1 History of architecture
- 4.2 Contemporary world architecture
- 4.3 Contemporary Nepalese architecture
- 4.4 Traditional architecture of Nepal
- 4.5 Architecture of Kathmandu Valley
- 4.6 Principles of architectural design.
- 4.7 Factors to be considered while designing buildings.
- 4.8 Standards to be followed while designing buildings in Nepal
- 4.9 Contemporary world architects and their works
- 4.10 Architectural landmarks in Nepal
- 4.11 Conservation of historic buildings.
- 4.12 Ethics of architects in professional practice.

द्वितीय पत्रको एकाईहरूको प्रश्नसंख्या निम्नानुसार हुनेछ ।

द्वितीय पत्रका खण्ड	A	B	C	D
द्वितीय पत्रका एकाई	1	2	3	4
प्रश्न संख्या	3	2	3	2

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Section - A

Building Materials and Construction

1.1 Stone masonry: Types of stone used in stone masonry, specifications of stone masonry

Stone is a natural material derived from rocks. It has no definite shape but is a mixture of two or more minerals. Masonry is the construction of building units bonded together with mortar. When stones are used as building units, the masonry is called stone masonry.

Types of stone masonry

a) Rubble masonry

In rubble masonry, the blocks of stones that are used are either undressed or comparatively roughly dressed. The masonry has wide joints since stones of irregular size are used.

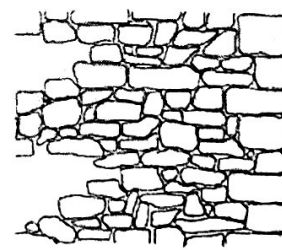
i) Random rubble

- **Un-coursed**

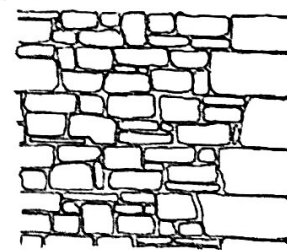
It is the roughest and the cheapest form of stone walling. Since stones are not of uniform shape and size, they are arranged with great care so as to distribute pressure over maximum area and at the same time avoid long vertical joints.

- **Built to course**

It is similar to un-coursed except that the work is roughly levelled up to form courses 30 to 45 cm thick.



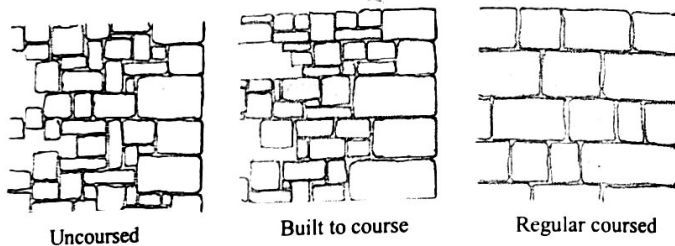
Uncoursed



Built to course

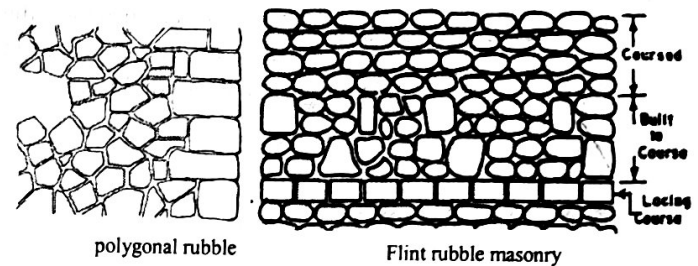
ii) Square rubble

- Un-coursed
Stones having straight beds and sides are arranged in irregular pattern to give good appearance and avoid the formation of long, continuous joints.
- Built to course
Stones having straight bed and sides are levelled up to form courses of varying depth.
- Regular coursed
Stones having straight beds and sides are levelled up to form courses of varying depth but the height of stones in each course, is the same.



iii) Miscellaneous type

- Polygonal rubble masonry
In this type, stones are hammer finished on face to an irregular polygonal shape. If stones are roughly shaped to form rough fitting, such a work is called rough picked work. If stones are carefully shaped to form close fitting, such a work is called close-picked work.
- Flint rubble masonry
In this type, flints or cobbles which vary in width and thickness from 7.5 cm to 15 cm and length from 15 cm to 30 cm are used. The stones are extremely hard but brittle. Strength of such walls can be increased using lacing course of thin long stones or bricks at 1 to 2 m vertical intervals.



iv) Dry rubble masonry

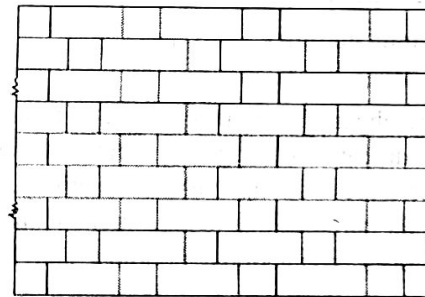
In this masonry, mortar is not used in the joints, so it is the cheapest and requires more skill in construction. It is mostly used for non-load bearing walls like compound walls.

b) Ashlar masonry

In ashlar masonry, square or rectangular blocks that are used are dressed and have extremely fine bed and end joints.

i) Ashlar fine tooled

It is the finest stone masonry. The beds, joints and faces of the stones are chisel dressed to remove all unevenness and obtain perfectly horizontal and vertical joints.



Ashlar fine tooled

ii) Ashlar rough tooled

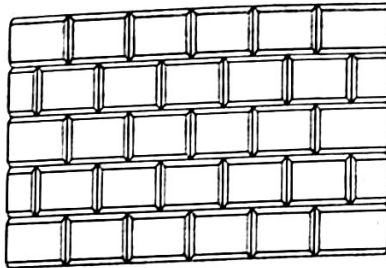
The beds and sides are finely chisel dressed but the exposed face is dressed by rough tooling.

iii) Ashlar rock faced

The exposed face of the stones is not dressed but is kept as such to give rough facing.

iv) Ashlar chamfered

It is a special type of ashlar rock faced in which the strip provided around the perimeter of the exposed face is chamfered at an angle of 45° to a depth of 25 mm.



Ashlar chamfered

v) Ashlar block in course

It is an intermediate between ashlar and rubble masonry. Faces of each stone are hammer dressed but the vertical joints are not as straight and fine as in ashlar masonry.

vi) Ashlar facing

It is provided along with brick or concrete block to give better appearance. The exposed faces of the stone are rough tooled and chamfered.

Types of stone used in stone masonry

a) Igneous stones

These stones are obtained from igneous rocks, formed from the cooling and solidification of magma generated within the Earth at high temperatures during volcanic activity. They are generally used for purposes that require strength and durability, such as kerbstones, countertops, floorings and breakwaters. Igneous stone ranges from very soft rocks such as pumice and scoria to somewhat harder rocks such as tuff and hard rocks such as granite and basalt.

b) Sedimentary stones

They are obtained from sedimentary rocks which are formed by accumulation and cementation of mineral grains (sediments) transported by wind, water or ice to a basin or by precipitation at a site. There are mainly two types of sedimentary stones used in masonry work, limestone and sandstone. Limestone is a

sedimentary rock composed largely of the minerals calcite and aragonite, which are different crystal forms of calcium carbonate. Limestone has numerous uses: as a building material, as aggregate for the base of roads, as white pigment or filler in products such as toothpastes or paints, and as a chemical feedstock. On the other hand, sandstone is a clastic sedimentary rock composed mainly of sand-sized minerals (mostly quartz and/or feldspar) or rock grains. It is relatively soft, making it easy to carve. Typically used as flooring or paving material, it has also been used for artistic purposes to create ornamental fountains and statues.

c) Metamorphic stones

They are obtained from metamorphic rocks, which are pre-existing rocks that have been altered by great heat and/or pressure or by chemical conditions. They have traditionally been used for carving statues, and as facing in many Byzantine and Renaissance Italian buildings. Slate and marble are metamorphic stones commonly used in the building industry. Slates are typically used for flooring, roofing and countertops whereas marbles are suitable for wall-cladding, roofing, flooring and all other interior and exterior applications.

Requirements of stone

- Appearance and general structure: Stones used for face work should have homogeneous color, should be resistant to weathering agencies and must be able to receive polish.
- Weight: Stones should be dense and less porous; good building stones should have specific gravity between 2.4 and 2.8. When used for domes, roof coverings etc., lighter varieties of the stones are preferred.
- Hardness and toughness: Stones used in floors and pavements should be hard enough to resist abrasive forces caused due to wear and friction. They should also be tough enough to withstand stresses developed due to vibrations of machinery and moving loads over them.
- Durability: Stones should possess natural durability to withstand destructive effects of various agents continuously operating on them. The durability of a stone depends upon the relation between its chemical composition and the atmospheric

surroundings. The texture of the stone also influences its durability. Crystalline homogeneous and close-grained varieties of stones with dense structure should be selected for good works. The surface of a freshly broken stone should be uniform in texture, color and hardness. Porous stones or those containing patches of soft or objectionable materials are liable to disintegrate quickly.

- e) Fire resistant: The minerals composing the stone should be such that the shape of the stone is preserved when a fire occurs. Limestone resists fire up to a temperature of 800 °C. Sandstone with silicates as binding material can resist fire very well.
- f) Workability: The stones should be such that they can be easily carved, molded, cut and dressed. It is an important consideration from economic point of view. However, this property of stone is opposed to its strength, durability and hardness. Hence, it is to be properly correlated with respect to the situation in which the stone is to be used.

Specification of stone masonry

Mortar shall comply with IS 2250-1981; Code of Practice for preparation and use of masonry mortar. Construction shall be carried out in accordance with IS 1597-1992; Code of Practice for construction of stone masonry, Part 1 Rubble Masonry or Part 2 Ashlar Masonry as appropriate.

- a) The mortar used in work shall have strength not less than 5 N/mm² or 7.5 N/mm² at 28 days as specified. Mortar shall be fluid, mixed thoroughly and then poured in the joints.
- b) All stratified stone possessing bedding planes shall be laid with its natural bed as nearly as possible at right angles to the direction of load. In the case of arch rings, the natural bed shall be radial.
- c) Except for dry rubble walling, all joints shall be sufficiently thick to prevent stone to stone contact and the gaps shall be completely filled with mortar.
- d) Stones shall be clean and properly wetted before they are used so as to avoid sucking of water from mortar.
- e) The bed which is to receive the stone shall be cleaned, wetted and covered with a layer of fresh mortar.

- f) All stones shall be laid full in mortar both in bed and vertical joints and settled carefully in place with a wooden mallet immediately after placement and solidly embedded in mortar before it has set.
- g) Clean and wet chips and spalls shall be wedged into the mortar joints and bed whenever necessary to avoid thick joint or bed of mortar.
- h) Dressing of the stones shall be done before they are laid and as per the stipulated requirement.
- i) Continuous vertical joints shall be avoided.
- j) Verticality of the wall shall be frequently checked with plumb-bob.
- k) Through stones shall be used within 1.5 m distance.
- l) The height of masonry shall be raised uniformly.
- m) Under the beams, trusses, sills, etc., large flat stones shall be used.
- n) Before continuing work, the masonry built on previous day shall be well cleaned and freed from loose particles.
- o) Curing shall be done properly for 2 to 3 weeks.
- p) Masonry shall not be laid when the air temperature is less than 3°C. Newly laid masonry shall be protected from the harmful effect of weather.

Use of different stones

- a) Granite: It is used in facing work, walls, steps, sills, bridge piers, columns and road metal.
- b) Gneiss: It is used in street paving and rough stone masonry wall.
- c) Marble: It is used in flooring, steps and ornamental work as it can be carved easily and at the same time, it can take nice polish.
- d) Slate: It is mostly used in roofing work and also in sills and damp-proof courses.
- e) Quartzite: It is used in retaining walls, road metal. Concrete aggregate, pitching rubble masonry and facing of buildings.
- f) Sandstone: It is used in facing work, steps, columns, flooring, walls, road metal and ornamental carving.
- g) Limestone: It is used in floors, steps, walls, road metal, manufacture of lime in blast furnace etc.

- h) Basalt and trap: It is used in road metal, for rubble masonry, foundation works etc.
- i) Laterite: It is used as building stone and in road metal and rough stone masonry work.
- j) Murum: It is a metamorphic rock, which is brown or red in color. It is used in road metal and garden walls.
- k) Chalk: It is pure white limestone which is soft and easy to form powder. It is used in the manufacture of Portland cement and the preparation of glazier's putty.

1.2 Brick masonry, Classification of bricks, specifications of different types of bricks, testing of bricks, different shapes of bricks

Classes of brick

- a) First class: These bricks are thoroughly burnt, have uniform color, water absorption less than 15% and minimum compressive strength of 10.5 N/mm^2 . They have plane, rectangular faces with parallel sides and right angled edges.
- b) Second class: They have distorted round edges and slightly rough surface with water absorption below 20% and minimum compressive strength of 7 N/mm^2 .
- c) Third class: They are not uniform in shape and are slightly under burnt or over burnt. Such bricks shouldn't have water absorption more than 25%.
- d) Over burnt (Jhama) brick: They are over-burnt, irregular in shape, hard and strong. These bricks are used in foundation, road material and flooring.

Requirements of good brick

- a) It should be well burnt and have uniform red color.
- b) It should give clear ringing sound when struck against another brick.
- c) When a brick is let to freely fall from 1 m on a hard floor, it should not break.
- d) It should not be scratched by finger nail.
- e) It should have uniform structure throughout its body without any distortions.

Specification of different types of bricks

- a) Machine made bricks
Bricks shall be of uniform deep red or copper color, thoroughly burnt without being vitrified, regular in shape and size and shall have sharp and square sides and edges and parallel faces to ensure uniformity in the thickness of the courses of brickwork. Bricks shall be first class machine made bricks of quality approved by the engineer and free from grit and other impurities such as lime, iron and other deleterious salts. They shall be uniform shaped, well-burnt, sound and hard with sharp edges and shall emit ringing sound when struck with a mallet. The size of the brick shall be $24\text{cm} \times 11.2\text{cm} \times 5.7\text{cm}$ unless otherwise specified, with a tolerance of 63mm in each direction. The compressive strength shall be more than 3.5 N/mm^2 .
- b) Chimney made bricks
Bricks shall be first class chimney made bricks of quality approved by the engineer and free from grit and other impurities such as lime, iron and other deleterious salts. They shall be uniform shaped, well-burnt, sound and hard with sharp edges and shall emit ringing sound when struck with a mallet. The size of the brick shall be $22.9\text{cm} \times 11.2\text{cm} \times 5.5\text{cm}$ unless otherwise specified, with a tolerance of 63mm in each direction. The compressive strength shall be more than 3.5 N/mm^2 . The bricks shall be provided with frogs.
- c) Dachi bricks
Bricks shall be machine pressed chimney made traditional bricks of first class quality approved by the engineer and free from grit and other impurities such as lime, iron and other deleterious salts. They shall be uniform shaped, well-burnt, sound and hard with sharp edges and shall emit ringing sound when struck with a mallet. The size of the brick shall be $21.8\text{cm} \times 10\text{cm} \times 5.6\text{cm}$ unless otherwise specified, with a tolerance of 62mm in each direction. The compressive strength shall be more than 3.5 N/mm^2 . All bricks shall be built in stretcher bond. Each brick shall be set with bed and vertical joints filled thoroughly with mortar finished in Surkhi pointing.

Tests for brick

a) Compressive strength test

Apparatus:

- Compression testing machine

Procedure:

Place the specimen with flat faces horizontal and mortar filled face facing upwards between two 3-ply plywood sheets each of 3mm thickness and carefully centered between plates of the testing machine. Apply load axially at a uniform rate of 14 N/mm² per minute till failure occurs and note the maximum load at failure. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in indicator reading on the testing machine.

Result:

$$\text{Compressive strength} = \frac{\text{Maximum load at failure}}{\text{Average area of bed faces}}$$

b) Water absorption test

Apparatus:

- Balance
- Ventilated oven

Preconditioning:

Dry the specimen in a ventilated oven at a temperature of 105 to 115° C till it attains substantially constant mass. Cool the specimen to room temperature and obtain its weight (M₁). Specimen warm to touch shall not be used for the purpose.

Procedure:

Immerse completely dried specimen in clean water at a temperature of 27 ± 2° C for 24 hours. Remove the specimen and wipe out any traces of water with a damp cloth and weigh the specimen. Complete the weighing 3 minutes after the specimen has been removed from water and record the weight (M₂).

Result:

$$\text{Water absorption} = \frac{M_2 - M_1}{M_1} \times 100\%$$

c) Efflorescence test

Apparatus:

- Glass or porcelain dish 180mm X 180mm X 40mm depth for square and 200mm diameter X 40mm depth for cylindrical shape

Procedure:

Place the end of the bricks in the dish, the depth of immersion in water being 25mm. Place the whole arrangement in a warm well ventilated room until all the water in the dish is absorbed by the specimens and the surplus water evaporates. Cover the dish containing the brick with suitable glass cylinder so that excessive evaporation from the dish may not occur. When the water has been absorbed and bricks appear to be dry, place a similar quantity of water in the dish and allow it to evaporate as before. Examine the bricks for efflorescence after the second evaporation and report the results.

Results:

The liability to efflorescence shall be reported as 'nil', 'slight', 'moderate', 'heavy' or 'serious' in accordance with the following definitions.

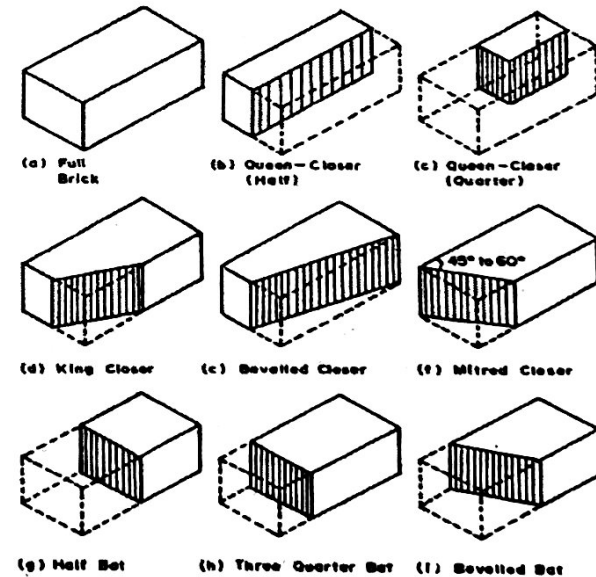
- Nil – When there is no perceptible deposit of efflorescence.
- Slight – When not more than 10 percent of the exposed area of the brick is covered with a thin deposit of salts.
- Moderate – When there is a heavier deposit than under 'slight' and covering up to 50 percent of the exposed area of the brick surface but unaccompanied by powdering or flaking of the surface.
- Heavy – When there is a heavy deposit of salts covering 50 percent or more of the exposed area of the brick surface but unaccompanied by powdering or flaking of the surfaces.
- Serious – When there is a heavy deposit of salts accompanied by powdering and / or flaking of the exposed surfaces.

Defects in brick masonry

- a) **Corrosion of embedded fixtures**
Such a defect is induced by dampness in brick walls. The iron or steel fixtures like pipes, frames or holdfasts embedded in the brick masonry get corroded due to dampness and hence expand with the formation of rust. This leads to cracking of brickwork. This defect is countered by using dense mortar cover of 15 to 25mm thick while embedding the fixtures.
- b) **Efflorescence**
It is phenomenon in which white patches of soluble salts form in the surface of the brick when such bricks come in contact with water. This defect is developed in bricks containing excessive soluble salts. Regular washing and brushing of the effected surface is remedial to such defect.
- c) **Shrinkage cracks**
The alternate swelling and shrinking of bricks due to absorption and evaporation of water respectively, causes cracks near the joints. Such defect can be minimized by using good quality bricks and by protecting brick walls from getting damp.
- d) **Sulphate attack**
This defect is prominent in places where the brickwork is exposed to moisture influence like in boundary walls, unplastered external walls, parapet walls, manholes, retaining walls etc. Sulphate attack relies upon a number of conditions occurring simultaneously; it requires water saturation over a relatively long period, a source of sulphates and reasonable amount of tricalcium aluminate. Even where these factors exist simultaneously, the attack will take a relatively long time to develop. In case of brickwork, the sulphate salts present in brick react with alumina of cement in case of cement mortar and with hydraulic lime in case of lime mortar provided that there is sufficient contact with water. This reaction increases the volume of mortar and leads to chipping and spalling of bricks. Sulphate attack can be checked by any technique that limits the entry of water in the body of brickwork.

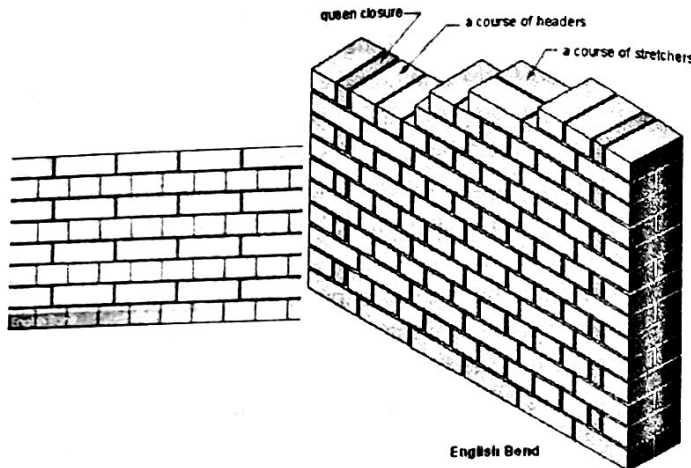
Forms of brick

- a) **Full brick**: It is the undisturbed brick having original shape and size.
- b) **Queen-closer**: When a brick is cut into two portions along its length, it forms queen-closer.
- c) **Queen-closer quarter**: When a queen-closer is broken into two pieces, it is known as queen-closer quarter.
- d) **King closer**: When a triangular piece of the brick lying between the center of one end and the center of its adjacent side, is removed, it forms a king closer.
- e) **Beveled Closer**: When the stretcher face of the brick is beveled in such a way that half width is maintained at one end and full width at the other end, it is known as beveled closer.
- f) **Mitred closer**: When a header of the brick is cut splayed or mitred at an angle of 45° to 60° for full width, it is known as mitred closer.
- g) **Half bat**: Bat is the portion of the brick cut along the width. If the bat length is half the original brick length, it is called half bat.
- h) **Three quarter bat**: When the length of the bat is equal to three-quarters of the length of a full brick, it is called three quarter bat.
- i) **Beveled bat**: Any bat which has its width beveled is called beveled bat.

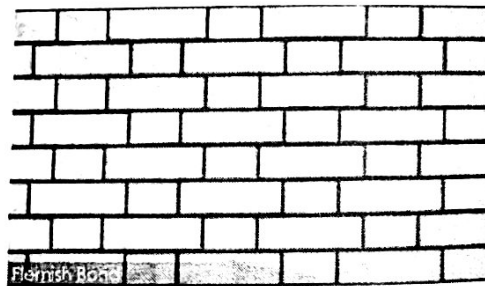


Brick bonds**a) English bond**

It consists of alternate courses of header and stretcher. Each header is placed centrally above each stretcher. To break the continuity of vertical joints, quoin closer is used in the beginning and end of a wall after first header. A quoin close is a brick cut lengthwise into two halves and used at corners in brick walls.

**b) Flemish bond**

Alternate bricks are placed as header and stretcher in every course. The thickness of Flemish bond, also called Dutch bond, is minimum one full



brick. The disadvantage of using Flemish bond is that construction of Flemish bond is difficult and requires greater skill to lay it properly as all vertical mortar joints need to be aligned vertically for best effects. For the breaking of vertical joints in the successive courses, closers are inserted in alternate courses next to the quoin header.

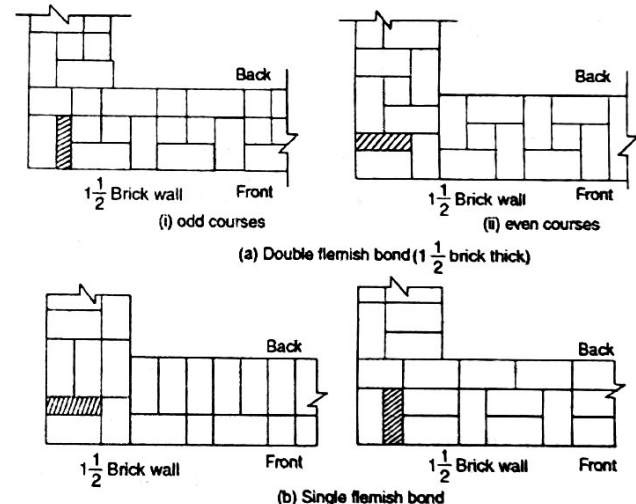
Flemish bonds have better appearance but are weaker than English bonds for load bearing wall construction. Thus, if the

pointing has to be done for brick masonry walls, then Flemish bond may be used for better aesthetic view. If the walls have to be plastered, then it is better to use English bond.

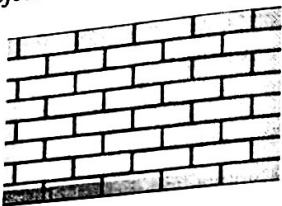
There are two types of Flemish bond:

Single Flemish bond is a combination of English bond and Flemish bond. In this type of construction, the front exposed surface of wall consists of Flemish bond and the back surface of the wall consists of English bond in each course. Minimum thickness required for single Flemish bond is one and a half brick thickness. The main purpose of using single Flemish bond is to provide greater aesthetic appearance on the front surface with required strength in the brickwork with English bond.

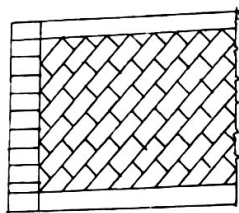
Double Flemish Bond has the same appearance both in the front and back elevations, i.e. each course consists of alternate header and stretcher. This type of bonding is comparatively weaker than English bond.

**c) Stretcher bond**

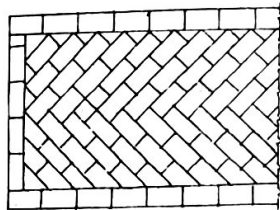
All bricks are laid with stretchers overlapping midway with the courses of bricks below and above, on the face of the wall. Also known as running bond, it is suitable for half brick partition walls in reinforced concrete frame structures. It is also used in boundary walls are parapets with supporting structures such as brick masonry columns at regular intervals.



- d) **Header bond**
All bricks are laid with headers overlapping midway with the courses of bricks below and above, on the face of the wall. It is used for the construction of full brick walls, but generally other bonds are preferred over header bond.
- e) **Raking bond**
Bricks are kept at an inclination to the direction of the wall.
- **Diagonal bond**
Bricks are inclined at 45° in the same direction and the extreme corners of the series remain in contact with the external line of stretcher.
 - **Herring-bone bond**
Bricks are inclined at 45° in opposite direction from the center of the wall thickness.

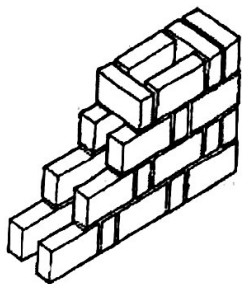


Plan showing arrangement of bricks in Diagonal bond



Plan showing arrangement of bricks in Herring-bone bond.

Rat trap bond and its advantages



A rat-trap bond is a type of wall brick masonry bond in which bricks are laid on edge (i.e. the height of each course in case of a brick size $230 \times 110 \times 75$ mm, will be 110 mm plus mortar thickness) such that the shinner and rowlock are visible on the face of masonry as shown in the figure.

This gives the wall an internal cavity which is the major reason that makes it possible to considerably save the bricks, sand and cement. This cavity adds a Green building feature that helps to maintain improved thermal comfort.

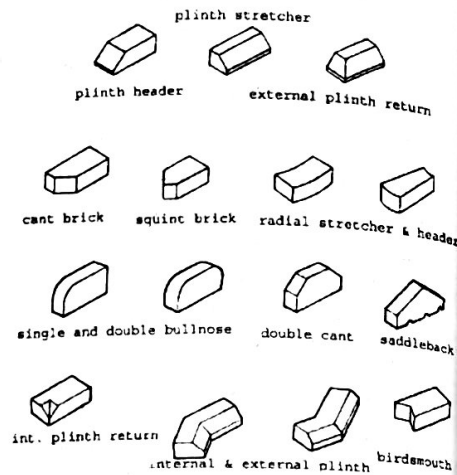
The Rat trap bond construction is a modular type of masonry construction. Due care must be taken while designing the wall lengths and heights for a structure. The openings and wall dimensions to be in multiples of the module. Also the course below sill and lintel to be a solid course by placing bricks on edge. The masonry on the sides of the openings also to be solid as will help in fixing of the opening frame.

The advantages of using rat trap bond are:

- By adopting this method of masonry, approx. 20-35% less bricks and 30-50% less mortar are required; also this reduces the cost of a 9 inch wall by 20-30 % and productivity of work enhances.
- For 1 m^3 of rat trap bond, 470 bricks are required compared to conventional brick wall where a total of 550 bricks are required.
- Rat trap bond wall is a cavity wall construction with added advantage of thermal comfort. The interiors remain cooler in summer and warmer in winters.
- Rat-trap bond when kept exposed, creates aesthetically pleasing wall surface and cost of plastering and painting also may be avoided.
- Rat trap bond can be used for load bearing as well as thick partition walls.
- All works such as pillars, sill bands, window and tie beams can be concealed.
- The walls have approximately 20% less dead weight and hence the foundations and other supporting structural members can suitably be designed, this gives an added advantage of cost saving for foundation.
- Service's installations should be planned during the masonry construction if not exposed.
- Materials such as bricks, cement and steel can be considerably saved by adopting this technology.
- In case for more structural safety, reinforcement bars can be inserted through the cavity till the foundation.

Shapes of brick

- a) Plinth header
- b) Plinth stretcher
- c) External plinth return
- d) Cant brick
- e) Squint brick
- f) Radial stretcher
- g) Radial header
- h) Single bullnose
- i) Double bullnose
- j) Double cant
- k) Saddleback
- l) Internal plinth return
- m) Internal plinth
- n) External plinth
- o) Birdsmouth



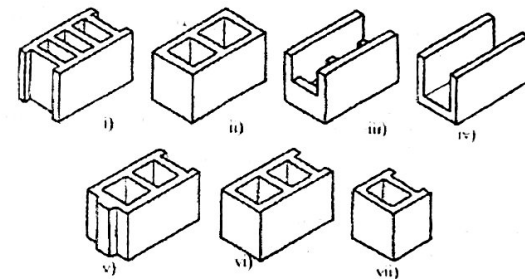
1.3 Hollow Concrete blocks: Various types of concrete blocks, use of concrete blocks in buildings

Hollow concrete blocks are light weight blocks used for load bearing as well as non-load bearing walls. Commonly used concrete block is of size 30cm X 20cm X 15cm. In general, for hollow concrete blocks, the face thickness must be at least 5 cm and the net area must be 55 to 60% of the gross area. The cement aggregate mix is 1:6 proportion. The strength of blocks should be at least 3 N/mm².

Types of concrete blocks

- a) Solid block: It is typically used in cavity or solid wall construction; also ideal for use in internal load bearing walls and Beam and Block floor systems.
- b) Hollow block
 - i) Stretcher (3 core): It is most common for unreinforced construction.
 - ii) Double Corner: Typically used for reinforced construction; Large cores with vertical steel bar and grout create internal reinforced concrete columns.

- iii) Low Web Bond Beam block: It provides space for horizontal reinforcing bar and grout. It is used to tie wall together at critical points or create a bond beam.
- iv) Channel Bond Beam or Lintel block: It provides space for horizontal reinforcing bar. It used to create lintels over openings.
- v) Control Joint: It is used for making expansion or vertical shear type control joints in construction. Sealant is used between interlocking units.
- vi) End block: It is used where the end of the unit will be exposed.
- vii) Corner block: It is a half block used at corners and ends of walls to create a running bond pattern.

**Advantages of using hollow concrete blocks**

- a) Construction is rapid as it needs no dressing.
- b) Blocks are light and easy to handle.
- c) There is great saving in materials.
- d) Due to large size, the number of joints in masonry is less thus saving mortar.
- e) Due to hollow space, the resulting wall has better insulating properties against sound, heat and dampness.
- f) The cost of block walls per m³ of masonry comes out to be about 15-20% lesser than that of brick walls. So, block masonry is economical.
- g) Maintenance cost of hollow concrete blocks is lesser because it has no efflorescence effect.
- h) It is eco-friendly because in hollow blocks, constituents can be substituted by waste products like fly ash.

- i) Blocks can withstand atmospheric action and do not require any plaster work.

1.4 Sand: Requirement of good quality sand, sieve analysis, Fineness modulus

Sand is a granular material made up of fine mineral particles. It is a naturally occurring, finely divided rock.

Requirements of good quality sand

- It should be clean.
- Sand to be used shall be well graded mixture from coarse to fine grains, complying with the requirements of IS 383 Latest edition or equivalent.
- For plastering purpose, the overall fine sand used must not have modulus less than 1.5 while silt is preferred not less than 4 percent.
- For brick work, fine sand used must not have modulus less than 1.2 to 1.5 and silt is preferred is 4 percent generally.
- Concreting works require coarse sand in modulus of 2.5 to 3.5 with not less than 4 percent silt content.
- It should be free from organic or vegetable matters.
- It should not have any trace of earth units.

Types of sand

- Based on particle size, sand is classified as Fine Sand (0.075 to 0.425 mm), Medium Sand (0.425 to 2 mm) and Coarse Sand (2.0 to 4.75 mm).
- Based on origin, sand is classified as Pit sand, River sand, Sea sand and Manufactured sand.
 - Pit sand: This type of coarse sand is procured from deep pits of abundant supply and it is generally in red-orange color. The coarse grain is sharp, angular and certainly free from salts etc., which is mostly employed in concreting.
 - River sand: It is procured from river streams and banks and is fine in quality unlike pit sand. This type of sand has rounded grains generally in white-grey color. River sand has many uses in the construction purpose such as plastering.

- Sea sand: As the name suggest, sea sand is taken from seas shores and it is generally in distinct brown color with fine circular grains. Sea sand is avoided for the purpose construction of concrete structure and in engineering techniques because it contains salt which tends to absorb moisture from atmosphere and bring dampness.
- Manufactured: It is a sand produced from crushing of granite stones in required grading to be used for construction purposes as a replacement for river sand. The manufactured sand has required gradation of fines, physical properties such as shape, smooth surface textures and consistency which makes it the best sand suitable for construction thus providing greater strength to the concrete by reducing segregation, bleeding, honeycombing, voids and capillary. Moreover, the usage of manufactured sand prevents dredging of river beds to get river sand which may lead to environmental disaster like ground water depletion, water scarcity, threat to the safety of bridges, dams etc. thus making manufactured sands more eco-friendly than river sand.

Sieve analysis

A sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution of a granular material. The size distribution is often of critical importance to understand the way the material performs during use.

Test procedure:

- Take a representative oven-dried sample of sand that weighs about 500gm.
- Determine the mass of sample accurately.
- Prepare a stack of sieves, sieves having larger opening sizes are placed above the ones having smaller opening sizes. A pan is placed at the bottom to collect the portion of sand passing through all sieves. Sieves of size 4.75mm, 2.36mm, 1.18mm, 600 μ , 300 μ , 150 μ and 75 μ are used to analyze.
- Pour the sand into the stack of sieves from the top and place the cover. Put the stack in the sieve shaker and fix the clamps, adjust the time to 10 - 15 minutes and get the shaker going.

- e) Stop the sieve shaker and measure the mass of retained sand in each sieve. Follow the sample format given below to obtain particle size distribution.

Sieve Analysis

Description of soil _____ Sample No. _____
Mass of oven dry sample, W _____

Location _____ Date _____
Tested by _____

Sieve No.	Sieve opening	Mass in grams of soil retained on each sieve	Percent of mass retained on each sieve, R	Cummulative percent retained, ΣR	Percent finer, 100 - ΣR
Pan	-				

Fineness modulus

It is an empirical factor obtained by adding the total percentages of a sample of the aggregate retained on each of a specified series of sieves and dividing the sum by 100.

1.5 Lime: Different types of lime and their uses, test of freshness

Lime is calcium oxide obtained by the calcination of limestone, kankar and other calcareous substances at over 900°C . It was one of the most common construction material before the advent of Portland cement. Wherever locally available, it is still a very popular and cheap construction material. It is used for plastering interior surface of walls, preparing concrete for foundation and flooring of ordinary buildings.

Types of lime

- a) Fat lime

Fat lime consists of mainly calcium oxide (CaO) which reacts with carbon dioxide (CO_2) in the air to form calcium carbonate after hardening.

- b) Hydraulic lime

It is a lime containing small quantities of silica and alumina and/or iron oxide which are in chemical combination with the calcium oxide content. It differs from fat lime in the process of hardening in

which it chemically combines with water to form calcium silicate and aluminate hydrate. Hydraulic lime hardens in combination with water while fat lime in combination with air.

ISI Classification of lime

- a) Class A: It is an eminently hydraulic lime normally used for structural purposes. It is usually supplied as hydrated lime.
- b) Class B: Semi hydraulic lime contains both hydraulic lime and fat lime. It is used for mortar in masonry work. It is supplied both as hydrated or quick lime.
- c) Class C: It is predominantly fat lime used for finishing coat in plastering, white washing etc. and with suitable admixtures such as Surkhi or any other pozzolanic material to produce artificial hydraulic lime. It is supplied both as quick lime and hydrated lime.
- d) Class D: It is lime containing substantial proportions of magnesium oxide and is similar to fat lime. It is used for finishing coat in plastering, white washing, etc.
- e) Class E: It is Kankar lime generally used for masonry mortars and is supplied generally as hydrated lime.

Terminologies in context to lime

- a) Quick lime: The calcined material, major part of which is calcium oxide in natural association with a relatively small amount of magnesium oxide and which is capable of slaking with water, is called quick lime.
- b) Fat lime: The lime which has high calcium oxide content and depends solely of the absorption of carbon dioxide for setting and hardening, is called fat lime.
- c) Hydraulic lime: Lime containing small quantities of silica and alumina and / or oxide which are in chemical combination with some of the calcium oxide content, giving a putty or mortar which has the property of setting and hardening under water, is called hydraulic lime.
- d) Hydrated lime: A dry powder obtained by treating quick lime with enough water to satisfy its chemical affinity for water under the condition of its hydration, is called hydrated lime.
- e) Lump lime: It is the quick lime as it comes from the kiln in the form of lumps.

Test of freshness of lime

When the original limestone has relatively low level of CaCO_3 and there are other components containing magnesia, silica, and alumina or if the limestone was poorly burnt so that the lime contained some original limestone, the fineness test is done to remove the non-lime components.

In the test, the lime is passed through a fine mess sieve of 0.18 mm and good quality lime hydrate should not have more than 1% retained on it. The principle behind the test is that hydrated lime very much finer than the impurities present and can pass through the fine sieve.

1.6 Mortar: Types of mortar, specifications, proportion of mortar for various types of masonry works**Types of mortar****Based on binding material****a) Cement mortar**

It consists of cement as a binding material, sand in different proportions and water. The ratio of cement to sand is normally 1:3 to 1:6 by weight. It is the strongest type of mortar and used in the construction of structures subjected to heavy loading.

b) Lime mortar

It consists of fat lime or hydraulic lime as a binding material, sand and water. The sand is added 2 to 3 times the volume of lime.

c) Lime-cement mortar

Also called gauged mortar, it is prepared by mixing cement with lime mortar in suitable proportion. It makes the mortar strong, economical and dense. The usual proportion of cement, lime and sand is 1:1:6, 1:2:9 or 1:3:12.

d) Mud mortar

Sticky clay is mixed with water until the required consistency is obtained. Sometimes fibrous materials are added to prevent shrinkage cracks. It is cheap and the ingredients are locally available.

e) Cement-clay mortar

Addition of clay in cement mortar in the ratio of cement to clay as 1:1 improves the grain composition, water retaining ability, density and workability of mortar.

f) Special mortars**i) Light weight mortar**

The paste is prepared by mixing wood powder, wood sawing or saw dust with cement or lime mortar. In such mortars, fibers of jute coir or asbestos fibers can also be used. These are generally used as fiber plasters in sound and heat proof construction.

ii) Fire-resistant mortar

It is prepared by adding aluminous cement to a finely crushed powder of fire bricks (1:2). It is generally used for lining furnaces, ovens and fire places with fire bricks.

Based on binding material**a) Heavy mortar**

The mortar which has a bulk density greater than or equal to 1500 kg per cubic meter in dry state, is called heavy mortar.

b) Light mortar

The mortar which has a bulk density lesser than 1500 kg per cubic meter in dry state, is called light mortar.

Proportion of mortar for various types of masonry works

a) Masonry exposed frequently to rains and where there is further protection by way of plastering or other finishes, the grade of mortar shall not be lesser than MM 0.7 (i.e., cement : lime : sand = 1:3:12 or cement : sand = 1:8) but shall preferably be of grade MM 2 (i.e., cement : lime : sand 1:2:9 or cement : sand 1:7). Where no protection is provided, the grade of mortar for external walls shall not be lesser than MM 2. For masonry in buildings subject to vibration of machinery, the grade of mortar shall not be lesser than MM 3. For parapets, where the height is greater than thrice the thickness, the grade of masonry mortar used shall not be lesser than MM 3 (i.e., cement: sand = 1:6).

b) In case of masonry in foundations laid below damp-proof course, the grades of mortar for use shall be as given below:

- Where soil has little moisture, masonry mortar of grade not lesser than MM 0.7 shall be used.
- Where soil is very damp, masonry mortar of grade preferably MM 2 or more shall be used. But, in no case shall the grade of mortar be lesser than MM 0.7.

- Where soil is saturated with water, masonry mortar of grade MM 3 (i.e., cement: sand = 1:6) shall be used but in no case shall the grade of mortar be lesser than MM 2.
- c) For the purpose of plastering, cement mortar with ratio 1:3 is used in concrete surfaces while in masonry surfaces, a ratio of 1:4 is used. The thickness of mortar is 12.5mm in general but in irregular surfaces typically in stone masonry walls 20mm thick mortar is required.
- d) For mortars serving fire resisting purpose, 1 part of aluminous cement and 2 parts of finely crushed powder of fire bricks must be used.
- e) The mortar used for pointing is of the proportion cement : sand = 1:1 to 1:2.

Field test of cement

It is not possible to check all the engineering qualities of cement on site but there exist some field test which gives us a rough idea of quality of cement. These field tests are as follows:

a) Date of packing

Date of manufacture should be seen on the bag. It is important because the strength of cement reduces with age.

b) Colour

The cement should be uniform in colour. In general the colour of cement is grey with a light greenish shade. The colour of cement gives an indication of excess lime or clay and the degree of burning.

c) Rubbing

When a pinch of cement is taken and rubbed, it should feel smooth. If it is rough, that indicates adulteration with sand.

d) Hand insertion

On thrusting hand into the cement bag, it should give cool feeling. This indicates that no hydration reaction is taking place in the bag.

e) Float test

While throwing a small quantity of cement in a bucket of water, it should sink and should not float on the surface.

f) Smell test

If the cement contains too much of pounded clay and silt as an adulterant, the cement paste will give an earthy smell.

g) Presence of lumps

Lumps should not be present in the bag of cement. It will ensure that no setting has taken place.

h) Shape test

For this test, the following procedure must be followed. Take 100g of cement and make a stiff paste. Prepare a cake with sharp edges and put on the glass plate. Immerse this plate in water. Observe that the shape shouldn't get disturbed while settling. It should be able to set and attain strength. Cement is capable of setting under water also and that is why it is also called 'Hydraulic Cement'.

i) Strength test

Several cement cubes of 7.06cm dimension are prepared. They are kept immersed in water. Some are tested at 7days under the compressive strength testing apparatus by loading the 50sqcm cross-section until failure and the breaking load is recorded. Similarly some are tested at 28 days and the breaking load per unit area is computed which should meet the required strength as per the type of cement used.

Paintings: Types of paints, specification for various types of painting works

Paint is a fluid paste prepared by dissolving a base into a vehicle along with a coloring pigment.

Essential ingredients of paint

- a) Base: It is the principle constituent of paint which consists of binding properties. It is a solid substance in fine state of division which imparts durability to the surface being painted. Eg, White lead, zinc white, red lead.
- b) Vehicle: It is the liquid that carries the material of the base and helps in even spreading on the surface. Eg, Linseed oil, soyabean oil.
- c) Pigment: It is the coloring substance. It is used when a color other than that of the base is desired. Pigments are available in

the form of fine powders in various colors and qualities. Eg, Zinc oxide, carbon, chrome yellow.

- d) Thinner / Solvent: It is the volatile substance added in paint to make its application easy and smooth. It helps the paint in penetrating through porous surfaces. Eg, naphthalene, turpentine.
- e) Drier: It is the substance added to quicken the process of evaporation. Eg, octates, resonates.

Types of paint

a) Oil paint

It is an ordinary cheap paint which is easy to apply. It is generally applied in three coats as prime, undercoat and finishing coat. It possesses good opacity and low gloss. It should be avoided in humid and damp weather.

b) Plastic paint

It contains necessary variety of plastics and is available in the market under different trade names. Its application can be done either by brush or spray painting. This paint possesses pleasing appearance and attractive color. It is widely used in auditoriums and show rooms.

c) Aluminum paint

Very finely ground aluminum is suspended in either quick-drying spirit varnish or slow-drying oil varnish as per requirement. The spirit or oil evaporates and a thin metallic film of aluminum is formed on the surface. It is widely used for painting gas tanks, hot water pipes, marine piers, oil storage tanks, radiators etc.

d) Cellulose paint

It is prepared from nitro-cotton, celluloid sheets, photographic films, etc. Unlike an ordinary paint which hardens by oxidation, a cellulose paint hardens by evaporation of thinning agent. Thus, it hardens quickly. It is little more costly than others but presents a flexible, hard and smooth surface. It is used in painting aircrafts.

e) Cement paint

It consists of white cement, pigment, accelerator and other additives. Available in dry powder form, it is water-proof and durable. It proves to be useful for surfaces which are damp at the

time of painting or are likely to become damp after painting. It is provided preferably in rough surfaces as it is less adhesive in nature.

f) Enamel paint

It contains white lead or zinc white, oil, petroleum spirit and resinous matter. The surface provided with this paint is not affected by acids, alkalis, fumes of gas, hot and cold water, steam etc. It is used for both internal and external walls.

g) Emulsion paint

It is easy to apply and dries quickly within 1.5 hours. The color is retained for a long period and the surface of the paint is tough and it can be cleaned by washing with water. It is used to paint wood or steel work which is to be built in masonry.

h) Asbestos paint

It is not a commonly used paint; typically applied on those surfaces which are exposed to acidic gases and steam.

Characteristics of ideal paint

- a) It should form hard and durable surface.
- b) It should be cheap and readily available.
- c) It should be dry in reasonable time.
- d) It should cover maximum area in minimum quantity.
- e) It should not form hair cracks on drying.
- f) It should form a film of uniform color.
- g) It should not be affected by atmospheric agencies.
- h) The paint should not affect the health of workers.
- i) It should possess attractive and pleasing appearance.
- j) The color of the paint must maintain for a long time.

Defects in painting

- a) Blistering: When water vapors trap behind the painted surface, it forms bubbles under the film of paint called blistering.
- b) Bloom: It is a defect characterized by the formation of dull patches on the finished polished surface.
- c) Fading: This is the gradual loss of color of the paint due to continuous solar exposure of pigments present in the paint.
- d) Flaking: It is the dislocation or loosening of some parts of the painted surface resulting from poor adhesion.

- e) Flashing: It is the formation of glossy patches on the painted surface, resulting from bad workmanship, cheap paint or weather action.
- f) Running: This defect occurs the surface of the painted area is too smooth thus resulting the paint to run back and leave small areas of the surface uncovered.
- g) Sponification: It is the formation of soap patches on the painted surface due to chemical action of alkalis.

Specification for various types of painting works

- a) White wash
Preparation of lime wash:

Lime wash shall be prepared from fresh stone white lime. The lime shall be thoroughly slaked on the spot, mixed and stirred with sufficient water to make a thin cream. This shall be allowed to stand for a period of 24 hours and then shall be screened through a clean coarse cloth. 40 gram of gum dissolved in hot water, shall be added to each 10 cubic decimeter of the cream. The approximate quantity of water to be added in making the cream shall be 5 liters of water to one kg of lime. Indigo (Neel) up to 3 gram per kg of lime dissolved in water shall then be added and stirred well. Water shall then be added at the rate of about 5 liters per kg of lime to produce a milky solution.

Preparation of surface:

Before new work is white washed, the surface shall be thoroughly brushed free from mortar droppings and foreign matter. In case of old work, all loose particles and scales shall be scrapped off and holes in plaster as well as patches of less than 50cm² area shall be filled up with mortar of the same mix. Where so specifically ordered by the engineer-in-charge, the entire surface of old white wash shall be thoroughly removed by scrapping. Where efflorescence is observed, the deposits should be brushed clean and washed. The surface shall then be allowed to dry for at least 48 hours before white washing is done.

Application:

The white wash shall be applied with moon brushes to the specified number of coats. The operation for each coat shall

consist of a stroke of the brush given from the top downwards, another from the bottom upwards over the first stroke, and similarly one stroke horizontally from the right and another from the left before it dries. Each coat shall be allowed to dry before the next one is applied.

For new work, three or more coats shall be applied till the surface presents a smooth and uniform finish through which the plaster does not show. The finished dry surface shall not show any signs of cracking and peeling nor shall it come off readily on the hand when rubbed.

For old work, after the surface has been prepared, a coat of white wash shall be applied over the patches and repairs. Then, a single coat or two or more coats of white wash as stipulated should be applied to present a uniform finish through which the plaster patches do not appear. The washing on ceiling should be done prior to that on walls.

Protective measures:

Doors, windows, floors, articles of furniture etc. and such other parts of the building not to be whitewashed, shall be protected from being splashed upon. Splashing and dropping, if any shall be removed by the contractor at his own cost and the surfaces cleaned. Damages if any to furniture and fixtures shall be recoverable from the contractor.

- b) Distemper work

Preparation of paint:

The washable distemper powder shall be stirred slowly in clean water using 0.6 liter of water per kg of distemper or as specified by manufacturer. Warm water shall preferably be used. It shall be allowed to stand for at least 30 minutes (or if practicable overnight) before used. The mixture shall be well stirred before and during use to maintain an even consistency. Distemper shall not be mixed in larger quantity than is actually required for one day's work.

Preparation of surface:

Before new work is distempered, the surface shall be thoroughly brushed free from mortar dropping and other foreign matter and sandpapered smooth.

Pitting in plaster shall be made good with plaster of Paris mixed with the color to be used. The surface shall then be rubbed down again with fine grade sandpaper and made smooth. A coat of distemper shall be applied over the patches.

Application:

For new work, the treatment shall consist of a priming coat of whitening followed by the application of two or more coats of distemper till the surface shows an even color. The plastered / POP surface should be properly cleaned and treated with water based primer as per manufacturer's specification. Rectification of defects in plaster / POP with broken edges shall be done by using a proper color putty paste as per manufacturer's specifications. For each coat of distemper, the entire surface shall be coated with the mixture uniformly with proper distemper brushes in horizontal strokes followed immediately by vertical ones, which together shall constitute one coat. The subsequent coats shall be applied only after the previous coat has dried. The finished surface shall be even and uniform and shall show no brush marks.

Enough distemper shall be mixed to finish one room at a time. The application of a coat in each room shall be finished in a single operation and no work shall be started in any room, which cannot be completed in the same day. After each day's work, the brushes shall be washed in hot water and hung down to dry. Old brushes, dirty or caked with distemper, shall not be used.

c) **Water proof cement paint work**

Preparation of paint:

Only fresh cement paint shall be used, hard or set paint shall not be used. The container, which must be stored in a dry place, shall be made loose by rolling and shaking the container before opening. Cement paint shall be mixed with water in two stages. First, a paste shall be prepared by mixing 2 parts of cement paint powder with one part of water by volume and immediately this shall be thinned by adding another part of water to have a uniform solution. Care should be taken to add the cement paint gradually to the water and not vice versa. The second stage shall

comprise of adding further one part of water to the mix and stirring thoroughly to obtain a liquid of workable and uniform consistency. In all cases, the manufacturer's instructions shall be followed meticulously.

Cement paint shall be mixed in such quantities as can be used up within an hour of its mixing as otherwise the mixture will set and thicken affecting flow and finish. The lids of cement paint shall be kept tightly closed when not in use, as by exposure to atmosphere the cement paint rapidly becomes air set due to hygroscopic qualities.

Preparation of surface:

Before application of paint, all dust and foreign materials shall be removed from the surface by use of wire brush. All holes, cracks and abrasions shall be filled with plaster of Paris, properly prepared and applied and smoothed off to match adjoining surfaces. Any loose or uneven areas or any major cracks or defects in the concrete or plaster background shall be cut out and made good and the repairs allowed to dry thoroughly. Any efflorescence shall be removed by dry brushing.

Application:

The fresh mixed paint shall be frequently stirred during application and no mixture (paint) shall be used after an hour of mixing. A vertical stroke with another horizontal stroke shall be termed one coat. Paint solution shall be applied to the surface with hair brush / roller in a number of coats to get uniform finish. After the first coat of the paint has hardened, it shall be cured with water at least for 24 hours before the second coat is applied. Similarly, required number of coats shall be given to get an even and uniform shade. It shall be kept damp at least for seven days. Sample of workmanship shall be approved by the engineer prior to commencement of work. The final painted surface shall exhibit uniform and good finished appearance.

d) **Enamel paint**

Acquisition of paint:

The primer and paint shall be of approved quality and of approved manufacturer like Asian Paints, Nerolac, Jensonlin,

Berger British Paints, Johnson and Nicholson or equivalent brand approved by the engineer. These materials shall be ready mixed and in sealed tins with the manufacturer's name, color and instruction clearly painted in the container.

Preparation of surface:

All surfaces to be painted shall be planned and thoroughly sandpapered, first by using No. 120 sandpaper. Ordinary putting shall fill up nail holes, cracks or other inequalities. Putting shall be made up of 2 parts of best quality whiting (absolutely dead stone lime) 1 part of white lead mixed together in linseed oil and kneaded (3 oz. of linseed oil to 1 lb. of whiting).

A primer coat shall be locally applied in holes, cracks etc. before putty is applied. The putty / paste fillers shall be of approved quality and shall be applied to the surface with a knife or other sharp edged tools after the priming coat as well as after each undercoat. After the surface is dry, it shall be sandpapered by using No. 60 sand paper. Surface so prepared shall be painted with one coat of primer. The primed surface when dry shall be sandpapered by using No. 100 sandpaper. The primed surface so prepared shall be painted with one coat of selected enamel using bristle brush. The paint shall be applied in thinnest possible layers with parallel strokes.

Care shall be taken to ensure the surface being free from dust or other foreign material before priming or enameling the surface. No paint shall splash on the floor, wall jambs, sill or other part of the building.

Application:

On wood work

After preparing and after the priming coat has been applied a topcoat shall be applied. The primed surface so prepared shall be painted with one coat of selected enamel using bristle brush and not horsehair ones. The same brand of materials will be used for various coats. The paint shall be used and applied with bristle brushes and not horse hair ones. The paints shall be applied in the thinnest possible layers with parallel drawings, no flowing

down shall not be allowed. Painting of false ceiling and acoustic materials such as thermo Cole, perforated acoustic tile, soft board etc. shall be done by spray painting only. The engineer prior to commencement of work shall approve sample of workmanship.

On metal surface

The paint shall be continuously stirred in the container so that its consistency is kept uniform throughout. The painting shall be laid on smoothly by means of crossing and laying off. The crossing and laying off consists of covering the area with paints, brushing the surface hard for the first time and then brushing alternatively in opposite directions, two or three times and then finally brushing lightly in a direction at right angles to the same. In this process, no brush marks shall be left after the laying-off is finished. The full process of crossing and laying-off will constitute one coat. Paints used shall be brought to required consistency by adding suitable thinner. Surface to be painted shall be clean, dry, smooth and adequately protected from dampness. Each coat shall be applied in sufficient quantity to obtain complete coverage, shall be well brushed and evenly worked out over the entire surface and into all corners, angles and crevices and allowed to thoroughly dry. Second coat shall be of suitable shade to match final color. Allow at least 48 hours drying time between coats for interior and 7 days for exterior work. Finished surfaces shall be protected from dampness and dust until completely dry. Finished work shall be uniform, of approved color, smooth and free from defective brushing and clogging. Edges of paints adjoining other materials or colors shall be made sharp and clean without any overlapping.

e) Chapra Polish

Preparation of polish:

The Chapra polish shall be made by mixing Chapra granules, thinner and spirit. The Chapra should completely dissolve in the spirit and the thinner should be used to obtain the required consistency.

Preparation of surface:

Before application of Chapra polish, the timber surface shall be thoroughly sandpapered to obtain smooth surface and all the dust shall be removed from the surface. A coat of primer of chalk powder mixed with resin or readymade approved putty shall be applied and sandpapered to fill in the voids and joints.

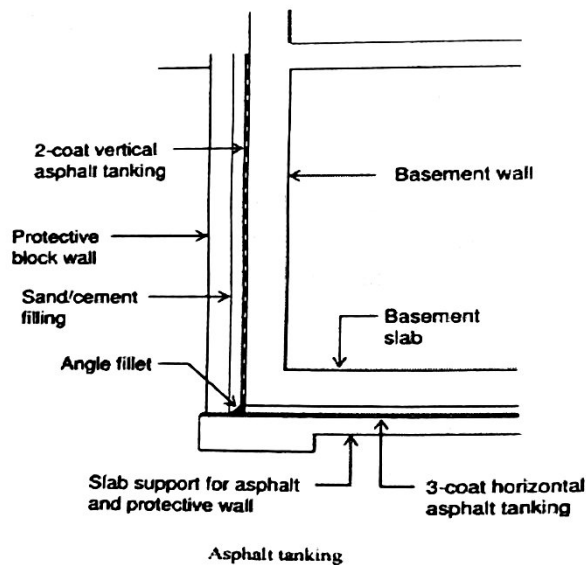
Application:

Over the primed surfaces, the Chapra polish of approved quality shall be applied with smooth cotton cloth with firm rubbing and spread evenly. The cloth shall be of good quality and perfectly cleaned. Chapra wood finish shall be reapplied at least three times, after sandpapering with fine sand paper to get the final finish and best result.

1.7 Water proofing: Water proofing at basement, ground floor and roofs, common water proofing problems in Nepal

Water proofing at basement

a) Asphalt tanking



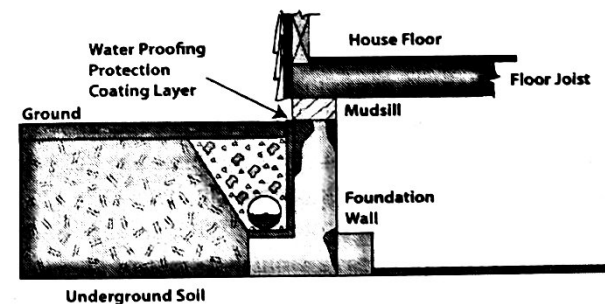
The common method of water proofing at basement is asphalt tanking. It is adopted when the subsoil water table is not very high. The treatment consists of horizontal DPC in the form of asphaltic layer of 30 mm thick in three coats over the entire area of the basement floor and then extending it in the form of vertical DPC 20 mm in three coats on the external faces of the basement walls. A $\frac{1}{2}$ brick thick outer protective wall is constructed. The vertical DPC is taken at least 15 cm above the ground level. A protective flooring of flat bricks on foundation concrete is provided to protect DPC from damage during the construction of floor slab.

b) Provision of RCC raft and wall slab

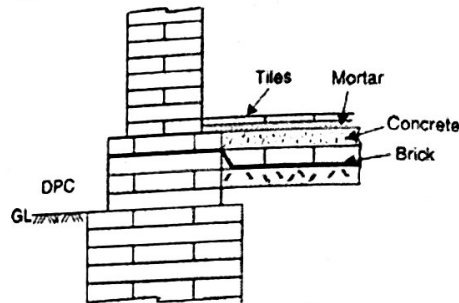
When the underground water pressure is severe, constant pumping may not be economically feasible. So, the floor slab as well as walls may be constructed in rigid RCC structure. Horizontal and vertical DPC treatment is provided in the form of 3 layers of bituminous felt and half brick protective wall is provided at the outer face of the RCC wall slab as in asphalt tanking.

c) Foundation air drains

When the basement rests on soils which are not properly drained, great hydrostatic pressure is exerted and the floor as well as the wall receives continuous oozing out of water. In such case, a trench is dug all around up to the foundation level and filled with gravel, coke or other pervious materials. A drain pipe with suitable longitudinal slope ultimately draining into a catch drain, is embedded in the gravel bed. Horizontal and vertical DPC are provided in the foundation concrete as shown in the figure below.



Water proofing at floors

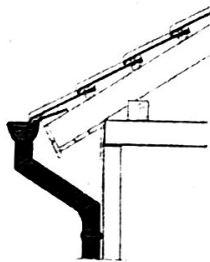


For water proofing at ground floor where ground moisture is not present, the subsoil is rammed and a 7.5 cm to 10 cm thick layer of coarse sand is spread over the entire area under flooring. Alternatively, stone soling may be provided above a 7.5 cm to 10 cm thick layer of lean cement concrete.

For damp soil, where water table is near the ground surface, a DPC membrane of mastic asphalt or fibrous asphalt felt is provided above a layer of lean cement concrete. A layer of flat bricks is laid over the DPC to protect from damage during the construction of floor slab.

Water drainage of roofs

Water drainage differs in case of pitched roof and flat roof.



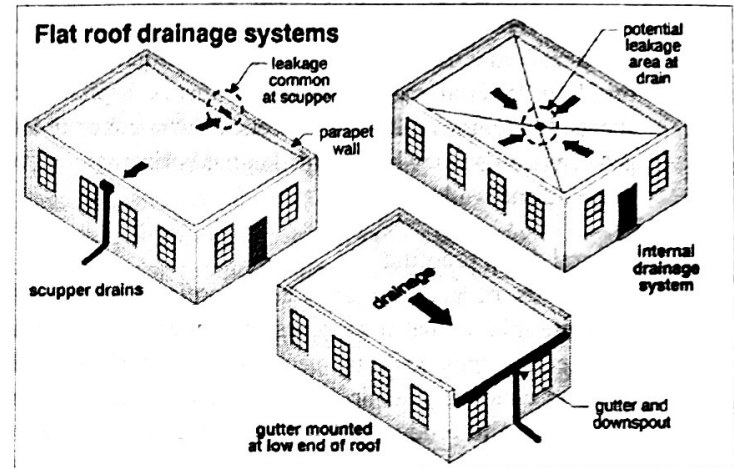
For pitched roof, a gutter is provided at the end of the slope and is extended for the full length of the roof. At suitable length along the gutter line, outlet points are provided where the ends of rain water pipes are fitted.

In case of flat roof, there are three commonly used methods.

a) Gutter and downspouts

The roof is provided with such a slope that the rain water is guided to the gutters and downspouts which carry the roof water away from the building protecting the cladding system and the foundation. This process is similar to that of sloped or pitched

roofs. The gutters and downspouts are most commonly made up of aluminum, galvanized steel, vinyl and copper.



b) Internal drains

Internal drains are typically connected to pipes that go down through the house and discharge into a storm sewer. The roof membrane is laid up to the edge of the drain opening. The drain, which includes a 3-inch flange around the top, is set into the membrane and then stripped in.

Drains are typically provided with a strainer to catch debris. Strainers have hinged top to allow for easy cleaning. Sometimes, a sediment collar is provided that will catch the sediment in the drain allowing water to drain down through holes, but holds the sediment around the outside of the pipe.

c) Scuppers

They are simply openings through parapet walls that allow water to drain into a downspout running down the exterior of the building. Scuppers are generally surrounded with a metal box. Good practice includes having a primary scuppers at the elevation of the roofing membrane and secondary scuppers about 2 inches above the low point to act as emergency drains in case the primary scuppers are obstructed.

Methods of damp proofinga) **Membrane damp proofing**

A water repellent membrane is inserted between the source of dampness and the part of the building adjacent to it. Damp proofing material may be bitumen, mastic asphalt, polythene sheets, bituminous felt, metal sheets, cement concrete etc. Damp proofing course may be provided either horizontally or vertically in floors and walls.

b) **Integral damp proofing**

It consists of addition of water proofing compounds to the concrete mix so that it becomes impermeable. The principle of these compounds could be mechanical in which they fill up the voids of concrete, chemical in which they react chemically with the concrete to produce water proof concrete or water repulsive principle in which the added compound makes the concrete water repellent.

c) **Surface treatment**

It consists of application of a layer of water repellent substance or compound on the surface to be protected so that it disallows the entering of moisture. The use of water repellent metallic soaps such as calcium and aluminium oletes and stearates are much effective against rain water penetration. However, overall this method is effective only when the moisture is superficial and not under pressure.

d) **Cavity wall construction**

It prevents penetration of water inside the building by shielding the main wall by an outer skin wall leaving a cavity between the two. It is an effective damp proofing technique.

e) **Guniting**

It consists of depositing under pressure, an impervious layer of rich cement mortar over the exposed surfaces for water proofing. Cement mortar consists of 1:3 cement sand mix which is shot on the cleaned surface at a distance of 75 to 90 cm with the help of a cement gun under a pressure of 2 to 3 kg/cm².

f) **Pressure grouting**

It consists of forcing cement grout, under pressure, into cracks, voids, fissures, etc. present in the structural components of the building thus consolidating them and enhancing their water penetration resistance.

Ideal material for DPC

- The material should be impervious so that it blocks moisture penetration.
- It should be strong, capable of resisting the super-imposed loads.
- The material should be flexible to accommodate the structural movement without fracture.
- It should form leak proof joints.
- It should be cheap and readily available in the market.
- It should be durable and should have same life as that of the building.

Common water proofing problems in Nepal

- Travel of moisture through walls and ceilings causes unsightly patches, softening and crumbling of plaster and paints.
- Breeding of mosquitoes and growth of termites are common due to dampness in buildings in Nepal.
- Warping, buckling and dry-rotting of timber fittings such as door, window, almirahs, and wardrobes are caused due to contact with damp walls and damp floors.
- Continuous presence of moisture in walls causes efflorescence resulting in disintegration of bricks, stones, tiles, and consequent strength reduction.
- Electrical fittings get deteriorated giving rise to leakage of electricity and danger of short-circuit.
- Rusting and corrosion of metal fittings attached to walls, floors and ceilings are due to moisture.

Common damp-proofing materials

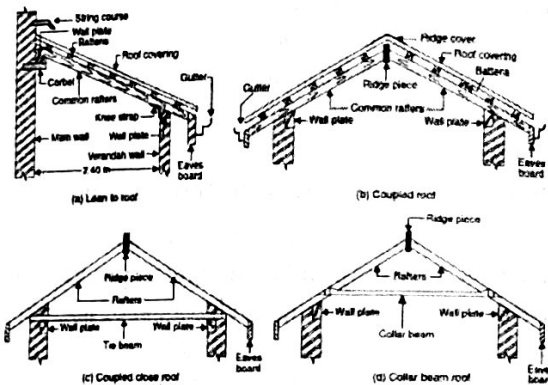
- Hot bitumen
- Bituminous felt
- Metal sheets
- Bricks
- Stones
- Plastic sheets

- g) Cement concrete
- h) Mastic asphalt

1.8 Roofing Systems: Different types of roofing system

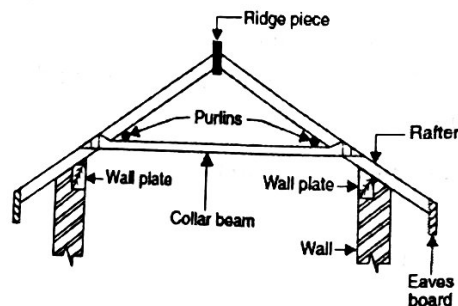
a) Single roof

It is a roof consisting only of rafters secured at the ridge and at the eaves. It is used when the span is less so that no intermediate support is required for the rafters. Roof may be of different forms like lean-to-roof, couple roof, couple close roof, collar beam roof etc.



b) Double roof

It is a roof which has two basic elements- rafters and purlins. Purlins give intermediate support to rafters and are supported on end walls. Each rafter is supported at the bottom of the wall, at the ridge and at the purlin. It is used when span exceeds 5 m.



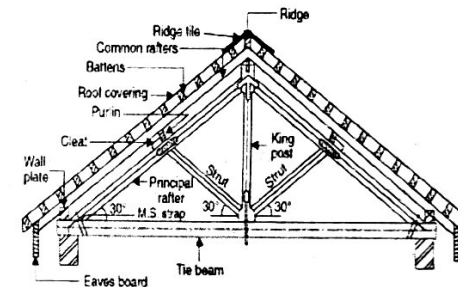
c) Triple roof

It is a roof which has three basic elements- rafters, purlins and trusses. When span exceeds 5 m and there is no inside wall to

support purlins, framed structures called trusses are provided at suitable intervals to support purlins. Rafters are supported on purlins and roofing materials are supported on rafters. For spans up to 9 m wooden trusses may be used but for larger spans steel trusses are a must. In case of wooden trusses suitable carpentry joints are made to connect various members at a joint. Bolts and straps are also used. In case of steel trusses joints are made using gusset plates and by providing bolts or rivets or welding.

Depending upon the span, trusses of different shapes are used. End of trusses are supported on walls or on column.

A typical king post truss is shown in the figure.



Requirement of good roof

- a) It should be durable against adverse effects of wind, rain, sun, dampness, snow etc.
- b) It should have proper drainage.
- c) It should be fire resistant.
- d) It should have proper arrangements for water proofing.
- e) It should have insulation against sound and heat.
- f) It should be structurally stable and strong enough to take loads likely to act over it.

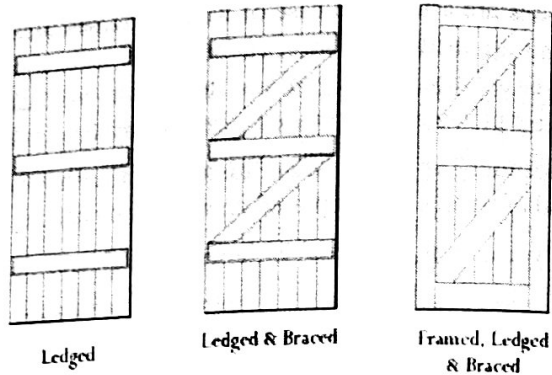
1.9 Doors and windows: Different types of doors and windows, door and window details, merits and demerits of metal door and windows

Types of door

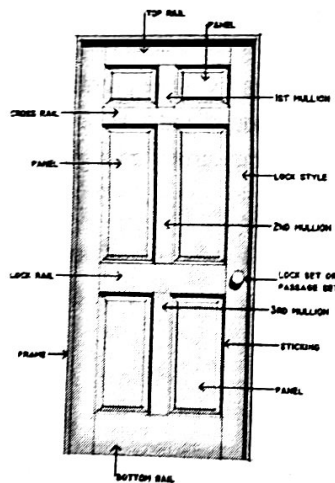
a) Lugged door

It is made up of timber boards or battens fixed in position by horizontal members known as ledges.

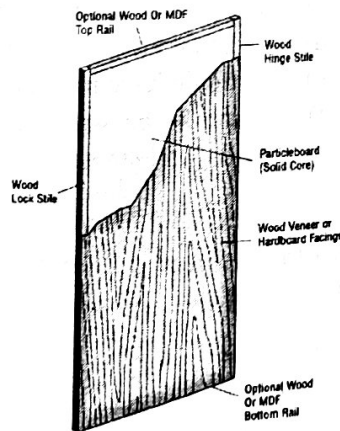
- b) **Ledged and braced door**
It is a ledged door which consists of a diagonal member known as brace to fix the battens in position.



- c) **Framed and paneled door**
It consists of a frame of vertical members called style and horizontal members called rail. Grooves are provided along the inner edges of the frame to receive panels, made of timber, plywood, AC sheet or even glass.
- d) **Flush door**
It is a solid or semi-solid skeleton or core covered on both sides with plywood, face veneer etc. presenting a flush and joint less surface.

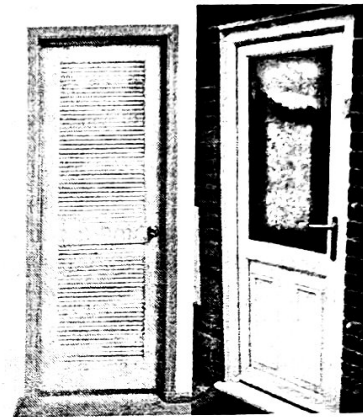


Framed and paneled door



Flush Door

- e) **Louvered door**
It is a door provided with louvers which may be opened and closed easily.

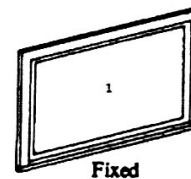


Louvered door Glazed door

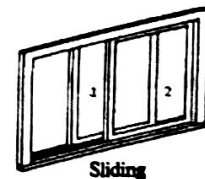
- f) **Glazed door**
It is a door made of either fully of partly glazed and partly paneled portion.

Types of window

- a) **Fixed window**
The window is used for the sole purpose of admitting light and providing vision in the room.



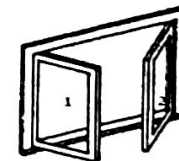
Fixed



Sliding



Double or single-hung



Casement

- b) Sliding window
These windows have shutters that move either horizontally or vertically on small roller bearings.
- c) Casement window
The window has a frame which is rebated to receive shutters which open like shutters of doors. The shutters consist of styles, top rails, bottom rails and intermediate rails thus dividing it into panels that may be glazed or unglazed.
- d) Double hung window
This type of window consists of a frame and a pair of shutters, arranged one above the other, which can slide vertically within the grooves provided in the window frame.
- e) Pivoted window
In this window, the shutters are allowed to swing round pivots fixed to the window frame.
- f) Glazed window
It is a casement window in which the panels are fully glazed.
- g) Louvered window
It is a window which consists of louvers, generally fixed, to provide ventilation but does not permit any outside vision.



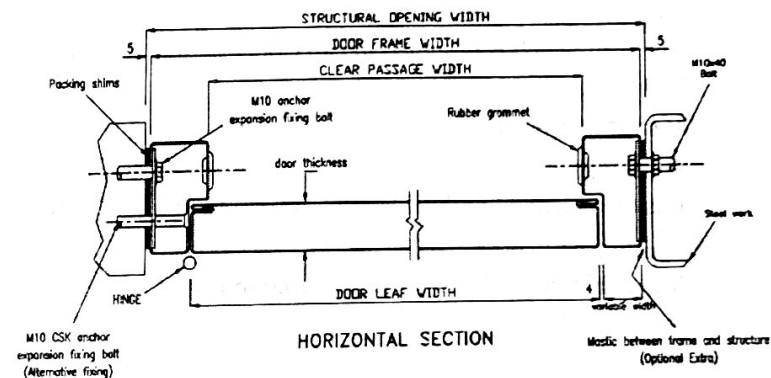
Merits of steel door / window

- a) Metal windows / doors are elegant with streamlined finishing.
- b) There is no expansion or contraction due to weather.
- c) It is rot and termite proof.
- d) It is fire-resistant.
- e) Metal doors have no tilting or twisting effect.
- f) Metal doors can be designed in any shape easily with minimum wastage.
- g) Metal doors take less space in fixing frames, due to this more opening space is available for the shutter in the doors.
- h) Metal frames have long life and their re-sale value is more.
- i) Using metal frame is being eco-friendly, as we save timber that would have otherwise been used in frames.
- j) Maintenance cost is negligible.

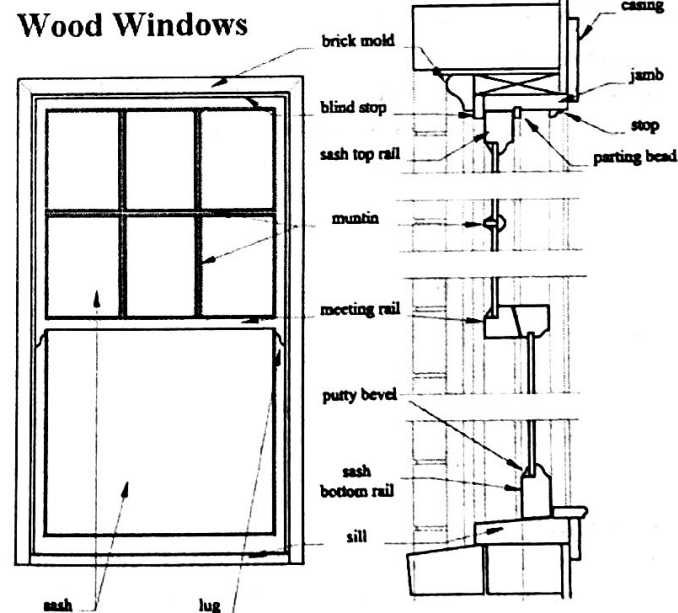
Demerits of metal door / window

- a) There is rusting problem in metal frames.
- b) They cannot give good architectural view.
- c) Their initial expenses are more compared to other modern doors and windows.

Wooden Door section details



Wooden Window details



1.10 Walls: Different types of wall system, Load bearing walls, partition walls and curtain walls

Types of wall

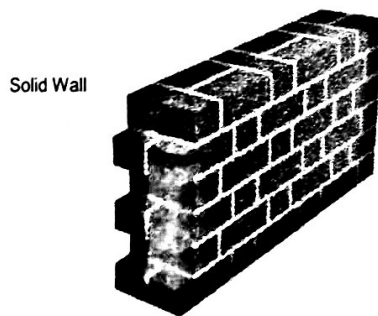
- Load bearing wall**
The wall which is designed to carry superimposed load in addition to its self-weight is called load bearing wall.
- Non-load bearing wall**
The wall which is designed to carry only its self-weight is called non-load bearing wall.

Other types of wall

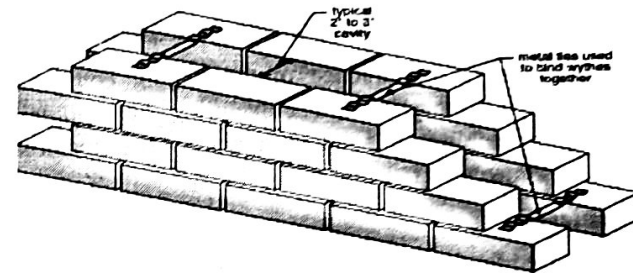
- Panel wall**
It is the external non-load bearing wall used in framed structure.
- Partition wall**
It is a thin internal wall which is used to divide space within the building into rooms or areas.
- Curtain wall**
It is a self-supporting wall which carries no other vertical load but is subjected to lateral loads.

Types of load bearing walls

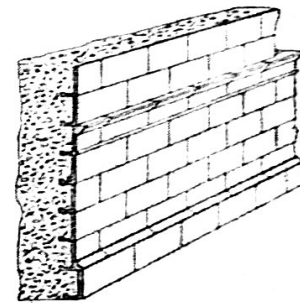
- Solid masonry wall**
It is the most common wall in which individual blocks of material such as bricks, concrete blocks or stones are used in horizontal courses with suitable mortar.



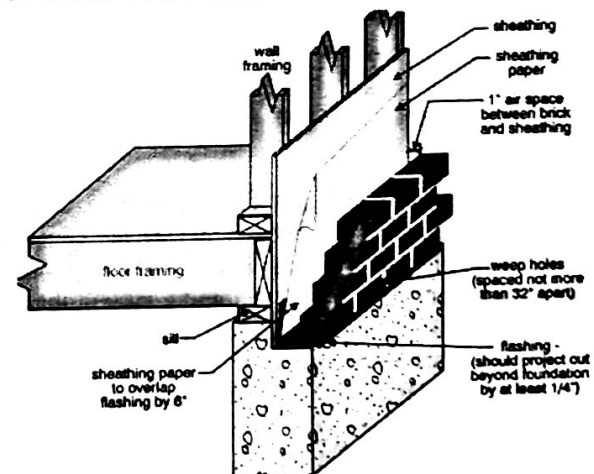
- Cavity wall**
It is a wall which consists of two leaves, each leaf built of structural units, separated by a cavity and tied together with metal ties.



- Faced wall**
It is a wall in which the facing and the backing are of two different materials and are bonded together to ensure common action under load.



- Veneered wall**
It is a wall in which the facing is attached to the backing but not so bonded to show common action under load.



1.11 Pre-fabrication: Principles of pre-fabrication, advantages and disadvantages of a pre-fabricated building

Pre-fabrication is the practice of assembling components of a structure in a factory or a manufacturing site and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located.

Advantages

- The need for formwork, shuttering and scaffolding is reduced.
- Construction time is reduced.
- On-site construction and congestion are minimized.
- Quality control is easier in factory than in construction site.
- Time spent due to bad weather or hazardous environment at construction site is minimized.
- Less wastage

Disadvantages

- Attention has to be paid to the strength and corrosion resistance of the joining of the prefabricated sections to avoid failure of joint.
- Leaks can form at joints in pre-fabricated components.
- High transportation cost has to be borne for transporting voluminous pre-fabricated sections.
- Larger pre-fabricated section requires heavy duty cranes to handle at site.
- Local jobs are lost.

Commonly used prefab materials in Nepal

Prefab materials are particularly used for walls and roofs.

a) Fiber Cement board

These are sandwich panel of two fiber-reinforced cement sheets enclosing a light weight core composed of Portland cement, binders and aggregate formed by mixing of siliceous and micaceous material. These panels have tongue and groove joining system that facilitates rapid construction with minimum effort. They are used in walls and have an overall thickness of only 50mm or 75mm as per requirement. They are available in 2' width and height varying from 8', 9' and 10'.

b) PUF panel

PUF panel consists of prefabricated sandwich panels made up of GI Sheet and poly-urethane foam material. These PUF panels are interlocked with each other using Cam Lock Systems or through Tongue and Groove arrangement, which ensures a precise interlocking of panels and dimensional accuracy. This eliminates the risk of thermal bridging and provides an air tight joints between panels after erection. PUF panels are available in a standard width of 1m and various thickness to suit the industry requirement. The standard thickness is 50, 60, 80, 100, 120, 150 and 200mm. They are available with both sides plain faced, generally used in walls and one side plain one side corrugated, used in roofs.

c) Rockwool panel

Rockwool panel system comprise of pre-fabricated composite sandwich panel of galvanized steel on both sides with high density rock wool converted to lamellar form in the inside joined with special joint sealants and fixing ancillaries. They are used in walls.

d) EPS panel

The EPS panel is made up by using Thermocol/EPS (Expand polystyrene) panel and covered by pre-coated metal sheets on both sides. Thermocol also known as Expanded Polystyrene (EPS) is a lightweight cellular paper material consisting of small hollow spherical balls. It is closed cellular construction that gives EPS panel its remarkable characteristics. It offers greater insulation properties as well as higher resistance to water absorption. EPS panel is a proven construction material well suited to the extreme climate. They are used in walls as well as in roofs.

1.12 Flooring: Different types of flooring, specification of flooring

Requirements of flooring material

a) Hard and durable

The flooring material should be hard to resist any indentation marks or imprints likely to be caused by shifting of furniture and equipment. It should also be durable. In that, it should be

resistant to wear, decay, disintegration, temperature fluctuation so that long life is obtained.

- b) Good thermal and sound insulation
Flooring should have good thermal insulation so that comfort is imparted to the residents. It should also insulate sound produced when users walk on it. Wood, rubber, PVC tiles are better for these purposes.
- c) Cheap and readily available
The initial cost of the material should conform to the type of building and its likely use. Materials should be readily available in the vicinity.
- d) Damp resistant
Flooring of concrete, terrazzo, mosaic are preferred for this purpose while that of cork, wood, rubber, linoleum, brick are not suitable for damp conditions.
- e) Smooth but not slippery
The flooring material should have smooth surface but it should not be slippery.
- f) Easy to maintain
The flooring material should require least maintenance. Whenever repairs are required, it should be such that repairs can be done easily with least possible expenditure. Hard coverings like marble, terrazzo, tiles require less maintenance than other materials.
- g) Fire resistant
Materials like concrete, terrazzo, mosaic and marble should be preferred for better fire resistance.

Types of flooring

- a) Brick flooring
It is used in warehouse and store. Bricks are laid on flat or on edge and arranged in a good looking pattern.

- b) Cement concrete flooring
It is used in residential, commercial and industrial buildings. It is cheap, durable and easy to construct.
- c) Granolithic flooring
Granolithic flooring is made of cement, sand and very hard tough quality coarse aggregate such as granite, basalt, quartzite etc. It is used when hard wearing surface is required.
- d) Terrazzo flooring
The flooring made with special aggregate of marble chips mixed with white and colored cement is called terrazzo flooring. It is used in residential buildings, hospitals, offices, schools etc.
- e) Mosaic flooring
It is made of small pieces of broken tiles of china glazed or cement, or of marble arranged in different pattern.
- f) Marble flooring
Marble slabs in square or rectangular shapes are laid. This flooring is used where excessive cleanliness is required as in bathroom, kitchen or hospitals.
- g) Tiled flooring
The flooring made of square, hexagonal or other shapes made of clay, terrazzo or cement concrete is called tiled flooring. It is used to replace terrazzo flooring.
- h) Asphalt flooring
It is not favored due to bad color and odor. But, at present, it can be used in different forms and color. It is recommended in swimming pool as it is non-slippery.

Specification of floorings

- a) Concrete flooring
Portland cement, clean sand and aggregate of 12mm nominal gauge shall be mixed on a watertight platform in the ratio of 1:2:4 or 1:4:8 or as specified in the drawing. All mix must be batched by volume except cement which shall be proportioned

by weight and as specified. The dry mixture shall be turned thrice till the color is uniform and then twice when wet. Water shall be added gradually and no more than necessary to sufficiently wet the materials. Only that much concrete shall be mixed which can be used within half an hour. Each stock of dry mix shall not be larger than consuming one bag of cement. In case of machine mixing IS code shall be strictly followed and mixing shall be done under the supervision of site-in-charge.

The subgrade shall be cleared off loose earth, rubbish and foreign matter. Cleaned subgrade shall be wetted with water thoroughly, but no water pool shall be allowed. Necessary slope shall be given to the subgrade itself. Concrete shall be laid in horizontal layers and gently rammed. It shall be compacted first with wooden float till all hollow spaces are filled by mortar paste. Then the surface is troweled till moisture disappears. The surface shall be checked with straight edge. Immediately after troweling, well mixed neat cement slurry mixed integrally with hardening liquid 2 liters to 50 kg of cement shall be sprinkled in a uniform layer at the rate of 2.2 kg per square meters. The cement slurry shall be troweled smooth with a steel float until approved finish is achieved. Curing shall be commenced until the top layer has hardened. Hardened concrete shall be kept wet for 15 days.

b) Brick soling

Brick soling shall be made in foundation and floor. It shall be done over 5 cm sand filling in line and level. Each brick shall be laid separately and tamped firmly in place in the sand bed. Joints between bricks shall be filled with dry sand. On completion, the surface shall be true to line and level with no part deviating by more than 20 mm.

c) Parquetting

The wooden parquet flooring shall be of natural wild shishum in standard size (like 70mm X 280mm X 12mm or 50mm X 300mm X 12mm parquet tiles) as approved by the engineer. The moisture content shall not be more than 8%. The parquet flooring shall be provided on neatly finished and leveled cement surface floor. The tiles shall be laid over standard base

of wood, using parquet adhesive in pattern approved by the engineer. The smoothly finished surface shall be sandpapered and finely finished with Chapra polish as approved. Over this surface, two coats of transparent laquer paints are applied.

d) Terrazzo flooring

Marble chips shall vary from 3mm to 6mm size. The concrete base is prepared as in cement concrete flooring. The top layer shall contain a 30mm thick cement concrete layer (1:2:4) laid over the base layer and a 5mm thick terrazzo topping. The entire area shall be divided into suitable panels of pre-determined size and shape using glass or aluminum strips; their height equal to the thickness of top layer. The surface of the base concrete shall be cleaned of dirt etc. and thoroughly wetted. The wet surface shall be smeared with cement slurry. Concrete of grade 1:2:4 is then laid in alternate panels, levelled and finished to rough surface. When the surface is hardened, the terrazzo mix (containing cement, marble chips and water) shall be laid and finished to the level surface. Additional marble chips may be added during tamping and rolling operation, so that at least 80% of the finished surface show exposed marble chips. The surface shall then floated and trowelled and left to dry for 12 to 20 hours. After that, curing shall be done for 2-3 days.

The first grinding shall be done, preferably by machine, using coarse grade (No. 60) carborundum stones using plenty of water. The ground surface shall then be scrubbed and cleaned. Cement grout of cream-like consistency shall be applied on the surface so that pores and holes are filled. The surface shall be cured for 7 days. Similar process shall be repeated in the second grinding using carborundum stones of fine grade (No. 120). In this case, 4 to 6 days of curing shall suffice. The final grinding shall be done using carborundum stone no. 320. The surface is again scrubbed and cleaned and then washed with dilute oxalic acid solution. Finally, the floor is polished with polishing machines, the wheels of which are fitted with felt or hessian bobs to get fine shine. Wax polish is also applied with the help of the polishing machine, to get final glossy surface.

e) Mosaic flooring

Broken tiles of china glazed or marble, cut to desired shape shall vary from 1.5mm to 3mm. A concrete base shall be prepared as in the case of concrete flooring and over it 5 to 8 cm thick lime surkhi mortar is spread and leveled over an area which can be completed conveniently within working period so that mortar won't get dried before the floor is finished. On this, a 3mm thick cementing material, in the form of paste two parts of slaked lime one part of powdered marble and one part of pozzolanic material shall be spread and left to dry for about 4 hours. Thereafter, small pieces of broken tiles or marble pieces of different colors shall be arranged in definite patterns, hammered into cementing layer and gently rolled by a stone roller sprinkling water over the surface so that the cementing material comes up through the joints to form an even surface. The surface shall be dried for 1 day and then rubbed with pumice stone fitted with a long wooden handle to get smooth and polished surface. The floor shall be dried for two weeks before use.

f) Marble flooring

Smooth and hard marble having uniform thickness and sharp edges from Godavari Marble factory or Rajasthani Marble or equivalent conforming to IS 1130 latest revision or British equivalent shall be used. The marble must be backed up with nylon grip net and shall be at least 20mm thick. Each marble stone slab shall be machine cut to required size and shape as specified in the drawing and as instructed by the engineer. All angles and edges of the marble shall be true and square and free from chippings and the surface shall be true and plane. Thickness shall be as specified in the drawing; no tolerance allowed. The base shall be made rough and watered and given cement wash and then the mortar shall be laid in 20mm thick layer. After laying mortar, it should be leveled with wooden floats. Proper slope for draining wash water shall be provided. Over this, marble stone shall be laid; the joints shall not be more than 3mm. The joints should be painted with white cement slurry. After about two hours of laying, the surface shall be covered with wet bags and kept wet and left undisturbed for two days.

Finally, when the surface is absolutely dry, oxalic acid powder shall be rubbed well on the surface with grinding machine with water and this operation shall be repeated until the surface becomes perfectly smooth and glossy. The surface shall be rubbed with wax to give a glazing surface. White cement or color cement shall be used in joint to have the required color as per specified. Care should be taken that the floor is not left slippery and that ordinary wax is not used under any circumstances.

1.13 Plastering: Different types of plaster and coating materials

Types of plaster

a) Lime plaster

It contains equal volume of lime and sand. The mixture is finely ground in a mortar mill. Fat lime is recommended for plaster work because it contains 75% of CaO and combines with CO₂ of atmosphere and gives CaCO₃ quickly. Thus, the lime sets quickly, but it imparts low strength and hence can be used for plaster work only.

b) Cement plaster

It contains one part of cement and 3 to 4 parts of clean, coarse and angular sand. The materials are thoroughly mixed in dry condition before water is added to them. Mixing is done in water tight platform and mortar prepared once is consumed within 30 minutes after adding water.

c) Stucco plaster

It is a decorative plaster with elegant finish like that of marble.

d) Water proof plaster

It consists of one part of cement and two parts of sand and pulverized alum 12 kg per cubic meter of sand. Water containing 75 grams of soft soap per liter is used for preparing the mortar.

Requirements of ideal plaster

- It should adhere firmly to the surface.
- It should not undergo volume change while drying and setting.

- c) It should provide a smooth, washable and good looking surface.
- d) It must be fire resistant.
- e) It should resist weathering effects.

Steps for plastering

- a) Preparation of the surface
The joints of the masonry are properly raked to a depth of 10 to 15 mm. The surface is cleaned with water and kept wet for 6 hours before plastering.
- b) Screed work for plaster
To obtain uniform thickness, wooden screed 7.5 cm wide and of required thickness of plaster are fixed vertically 2.5 to 3 m apart using plumb bob.
- c) Application of plaster coats
 - i) First coat
Lime plaster is dashed against the wall surface between the screeds with the help of a trowel and pressed well into the joints. It is 10 to 12 mm thick and is used to fill irregularities of the surface. The first coat is left to dry for 3 to 4 days.
 - ii) Second coat
The surface of the first coat is washed and scratched with the edge of a trowel. The lime plaster of the second coat is pressed against the wall surface and rubbed using a trowel to obtain an average thickness of 5 to 8 mm.
 - ii) Third coat
The third coat consists of fat lime called lime putty. It is evenly applied on the surface of the second coat and rubbed first with a wooden float and finally with a steel float to obtain a polished surface 3 to 5 mm thick. The final surface is allowed to dry for 2 days and then cured for 7 to 10 days.

1.14 Formworks: Shoring, underpinning, scaffolding and formworks

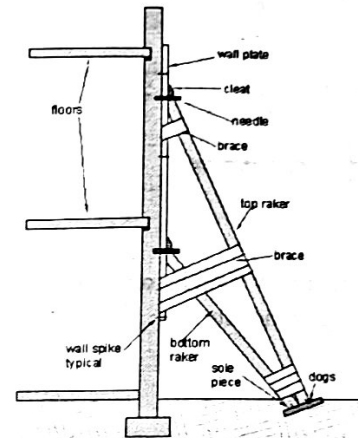
Shoring

Shoring is the construction of a temporary structure to support an unsafe structure.

Types of shoring

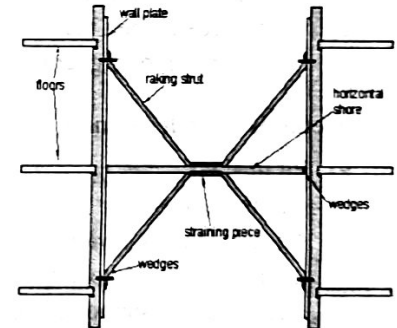
- a) Raking or inclined shore

In this method, inclined members called rakers are used to give temporary lateral support to an unsafe wall.



- b) Flying or horizontal shore

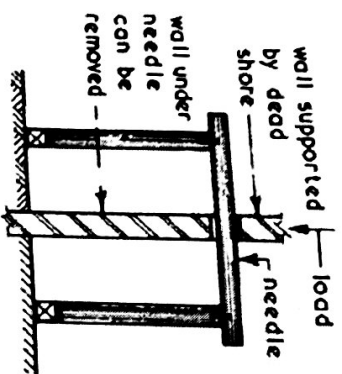
In this method horizontal temporary support is provided to two adjacent parallel party walls of the two buildings which have become unsafe due to removal or collapse of intermediate building.



Part Elevation Through Two Buildings With A Single Flying Timber Shore

- c) Dead or vertical shore

In this method, vertical support is provided to walls, roofs, floors etc. when the lower part of the wall has to be removed for the purpose of providing an opening in the wall.



Underpinning

It is the process of placing a new foundation under an existing one or strengthening an existing foundation.

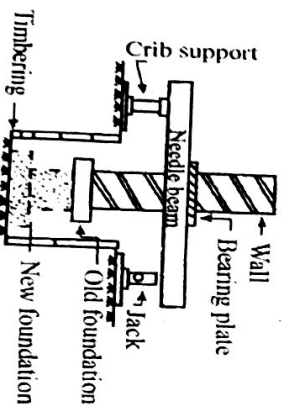
Needs of underpinning

- It is needed when settlement of the existing foundation has taken place resulting in cracks in the wall.
- It is needed when basement is to be provided.
- It is needed when the existing foundation is to be deepened to rest it on soil of higher bearing capacity.

Methods of underpinning

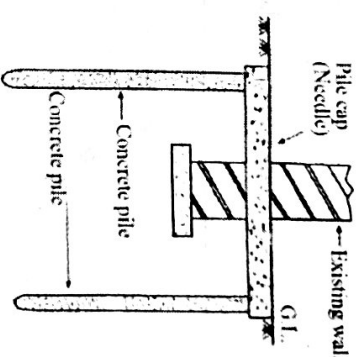
a) Pit method

In this method, the entire length of foundation to be underpinned is divided into sections of 1.2 to 1.5 m length. In each section, a hole is made through the wall to insert the needle beam supported on either side by wooden blocks and screw jack. The foundation pit is then excavated to desired level and a new foundation is laid.



b) Pile method

In this method, piles are driven at regular interval along both sides of the wall. The piles are connected by concrete or steel needles, penetrating through the wall.



Scaffolding

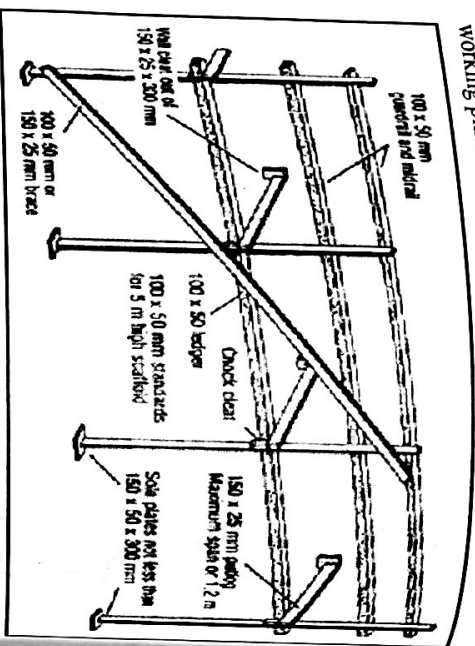
The temporary network erected to support a number of platforms at different levels for the convenience of the workers, is known as scaffolding.

Components of scaffold

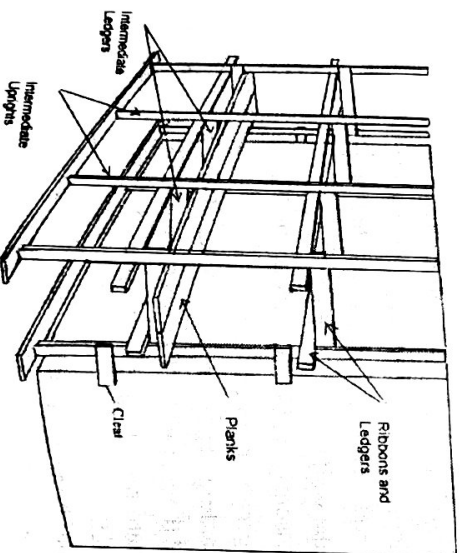
- Standards: They are vertical members supported or embedded on the ground.
- Ledgers: These are horizontal members running parallel to the ground.
- Braces: They are diagonal members fixed on standards.
- Putlogs: They are transverse members placed at right angles to the wall with one end supported on ledgers and the other end on the wall.
- Transoms: These are those putlogs which are supported on ledgers on both ends.
- Boarding: They are horizontal platforms that support workmen and the materials. Boards are supported on putlogs.
- Guard rail: This is a rail provided like a ledger, at the working level.
- Toe board: It is a board placed parallel to ledgers and supported at putlogs to give protection at the level of working platform.

Types of scars

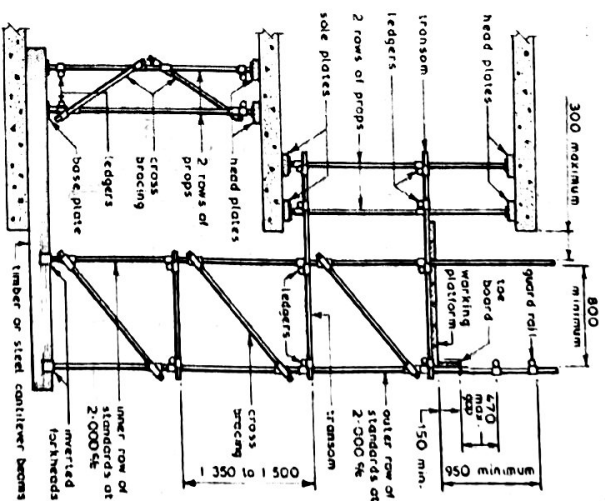
- working platform.



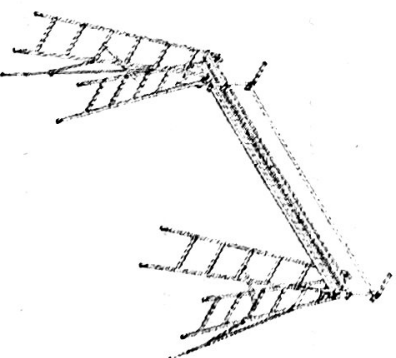
- It consists of ledgers and braces, one close to the wall and the other at a distance of 1.5 m from the first.



- The scaffolds are cantilevered and supported by a number of needles provided at floor level or through holes made in the wall. These are used only when it is impracticable, undesirable or uneconomical to use a traditional scaffold raised from ground level.

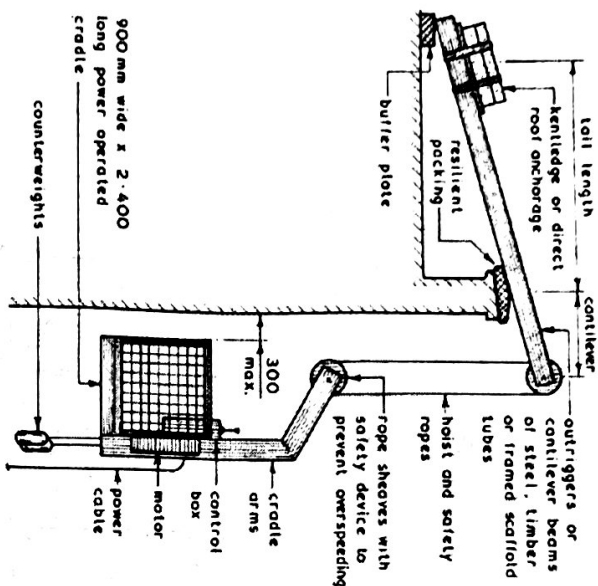


- Trestle scaffold**
It consists of a ladder or tripod carrying a working platform on the top.



e) Suspended scaffold

It consists of a working platform suspended from the roof with the help of chains or ropes and can be lowered or raised as required.



f) Steel scaffold

The scaffold in which steel pipes are used, is called steel scaffold. It can be erected quickly and has long life though costly.

Formwork

The formwork or shuttering is a temporary ancillary construction used as a mold for the structure, in which concrete is placed, hardened and matured.

Requirements of good formwork

- The material of formwork should be cheap and suitable for reuse.
- It should be water proof so that it does not absorb water from concrete.
- It should be strong to withstand loads coming on it and stiff to minimize deflection.

d) It should be light.

e) The surface of formwork should be smooth.

f) The formwork should rest on sound, hard and non-yielding support.

g) The formwork should be so arranged that there is minimum leakage through the joints.

Code provision for standard formworks

a) General

The formwork shall conform the shape, lines and dimensions, as shown on the plans and be so constructed as to remain sufficiently rigid during the placing and compaction of the concrete, and shall be sufficiently rigid during placing and compacting of concrete, and shall be sufficiently tight to prevent loss of liquid from the concrete.

b) Cleaning and treatment of forms

All rubbish particularly chippings, shavings and sawdust shall be removed from the interior of the forms before the concrete is placed and the formwork in contact with the concrete shall be cleaned and thoroughly wetted or treated with an approved composition.

c) Stripping time

In normal circumstance (generally when the temperature is above 20°C and where ordinary cement is used, forms may be struck after the expiry of the following periods.

- Walls, columns and vertical side of beams 24 to 48 hours
- Slab soffits (props left under) 3 days
- Beam soffits (props left under) 7 days
- Removal of props to slabs
 - Spanning up to 4.5 m 7 days
 - Spanning over 4.5 m 14 days
- Removal of props to beams and arches
 - Spanning up to 6 m 14 days
 - Spanning over 6 m 21 days

d) Procedure when removing formwork

All formwork shall be removed without such shock or vibration as would damage the reinforced concrete. Before the soffit and strut are removed, the concrete surface shall be

exposed, where necessary in order to ascertain that the concrete has sufficiently hardened.

- e) **Camber**
It is generally desirable to give forms an upward camber to ensure that the beams do not have a sag when they have taken up their deflection, but this should not be done unless allowed for in design calculations of the beams.
- f) **Tolerances**
Formwork shall be so constructed that the internal dimensions are within the permissible tolerance specified by the designer.

Materials used in formwork

- a) **Steel formwork**
Using steel in formwork increases the initial cost, but in the long run, it proves to be economical as it can be re-used several times, normally ten times more than timber formwork. It gives excellent exposed concrete surfaces requiring no further finishing treatment. It does not absorb water from the concrete and hence, the chances of the formation of honey-combed surface are minimum. It is easy to dismantle and possesses more strength and durability compared to others.
- b) **Conventional timber formwork**
It is generally used for small works requiring less repetitions since its initial cost is less. The timber to be used should be well-seasoned, free from loose knots, light in weight and easily workable with nails without splitting. These formworks can be re-used for 10 to 12 times.
- c) **Plywood formwork**
Using plywood in formwork is gaining popularity given that it presents a smooth surface that requires no further finishing treatment and can also be re-used normally 20 to 25 times. Plywood can be used to cover up large area so that it largely reduces the labor cost of fixing and dismantling of formwork.

1.15 Building elements

Foundation

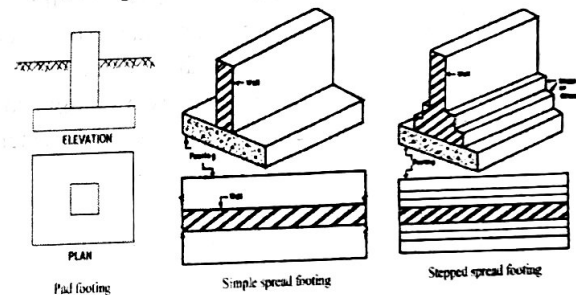
It is the part of the structure which transmits load from the superstructure to the soil beneath it.

Types of foundation

- a) **Shallow foundation**
If the depth of foundation is equal to or less than its width, it is called shallow foundation.

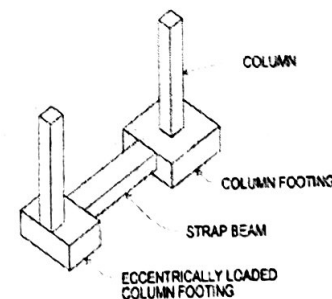
1. Spread foundation

It is a footing which supports either one wall or one column. The spread footing for wall is called strip footing and for column is called pad or isolated footing. Spread footing can be simple or stepped.



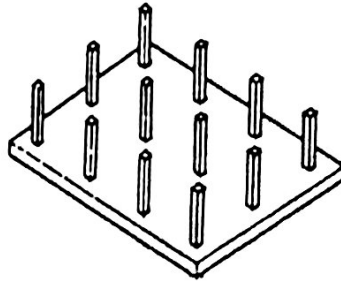
2. Strap footing

When two or more isolated footings are connected by a beam, it is called strap footing. It is used when the distance between the columns is so great that a combined trapezoidal footing becomes quite narrow with high bending moments.



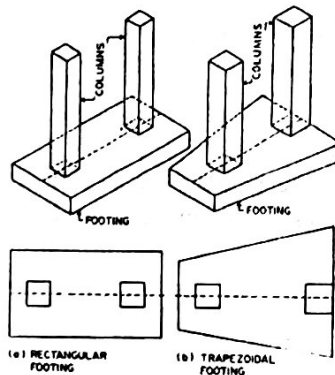
3. Mat foundation

A foundation consisting of thick reinforced concrete slab covering the entire area of the bottom of the structure is called mat or raft.



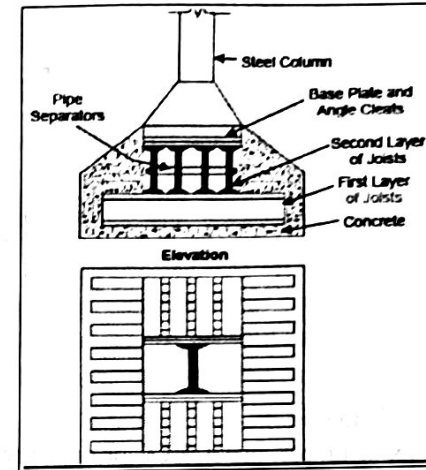
4. Combined footing

The common footing constructed for two or more columns is called combined footing. The shape of a combined footing is so proportioned that the CG of the supporting area is in line with the CG of the two column loads. The general shape of a combined footing is either rectangular or trapezoidal.



5. Grillage foundation

It is a special type of isolated footing, provided for heavily loaded steel stanchions, especially in those locations where bearing capacity of soil is poor. It consists of one or two tiers of wooden or steel sections with space filled up by concrete.



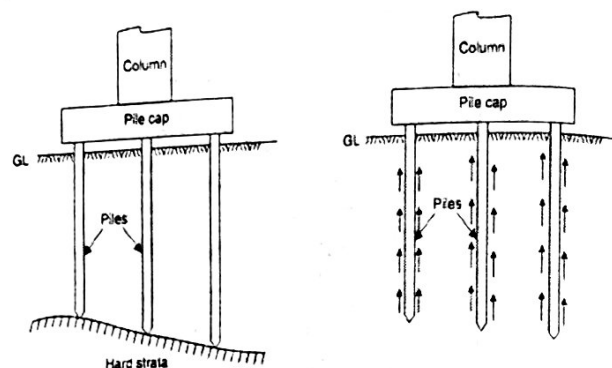
b) Deep foundation

The foundation in which the depth of the foundation is very large in comparison to its width is called deep foundation.

1. Pile foundation

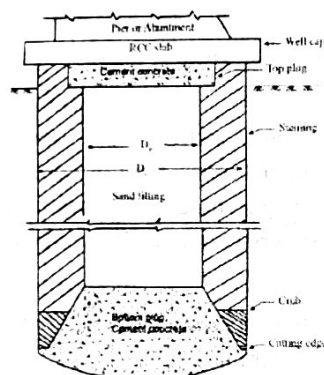
A pile is a long vertical load transferring member composed of either timber, steel or concrete. A number of piles is driven in the base of the structure to transfer the load from the superstructure to the soil beneath.

- **Bearing pile**
It transfers the superimposed load through them to hard strata at considerable depth.
- **Friction pile**
It transfers the superimposed load through them to soft soil by frictional forces developed between the soil and the pile surface.
- **Compression pile**
It is used to compact granular soil to increase its bearing capacity.
- **Batter pile**
It is used to resist large horizontal or inclined forces.



2. Well foundation

It is a box of timber, metal, RCC or masonry open at both ends and used in building and bridge foundation.



Causes of foundation failure

- Unequal sub-soil settlement
- Unequal settlement of structure
- Lateral horizontal earth pressure on the structure
- Shrinkage of sub-soil strata due to temperature variation
- Penetration of roots of trees below the foundation
- Seismic effect on foundation

- Securing of adequate allowable bearing capacity,
- In the case of clayey soils, penetration into the soil has to be below the zone where shrinkage and swelling due to seasonal weather changes and due to trees and shrubs are likely to cause appreciable movements,
- In fine sands and silts penetration has to be below the zone in which trouble may be expected from frost,
- The maximum depth of scour whenever relevant (say, in bridge piers) should also be considered and the foundation should be located sufficiently below this depth, and
- It should be below the top soil, miscellaneous fill, tree roots etc.

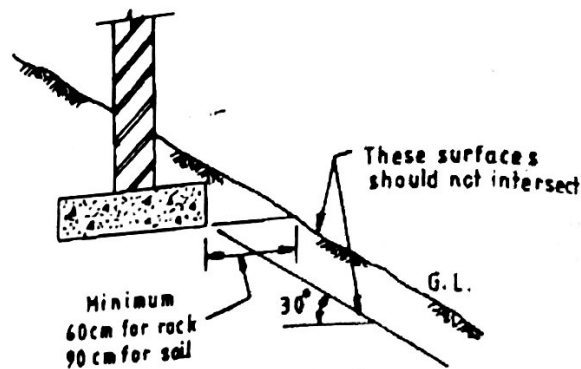
All foundations should be taken down to a **minimum depth of 0.5m** below natural ground level. In practice in Nepal, foundations are taken up to 1.5m to 2m for reinforced concrete buildings and 0.75m to 1m for masonry load-bearing buildings. In filled-up ground it may be necessary to go beyond the depth of fill or take special precautions. In such cases, it may be necessary for economic considerations to have the foundation at a higher level, and get the difference in level between the base of foundation and the level of excavation filled up with either:

- Concrete of allowable compressive strength not less than the allowable bearing pressure on the soil, or
- Incompressible fill material, for example sand, gravel etc. in which case the width of fill should be more than the width of foundation for dispersion of load on either side of the base of foundation.

In sloping grounds, the horizontal distance from the bottom edge of the footing to the ground surface shall be at least 60 cm for rock, and 90 cm for soil. A line drawn at an angle of 30 degree to the base from the outer edge should not intersect the sloping surface.

Depth of foundation

The depth to which foundation should be taken depends on the following principal factors:



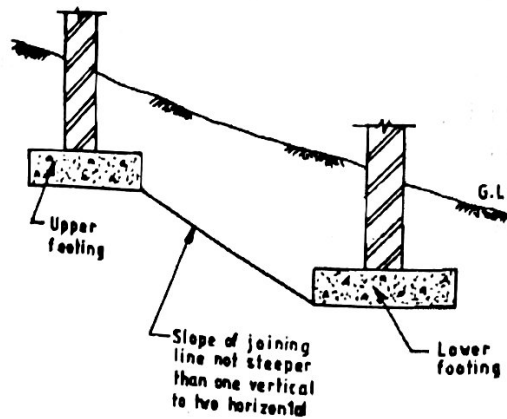
Foundation on sloping ground

Foundation near Existing Building

The minimum horizontal distance between existing and new footings shall be at least equal to the width of the wider footing. In important cases, analysis of bearing capacity and settlement shall be carried out.

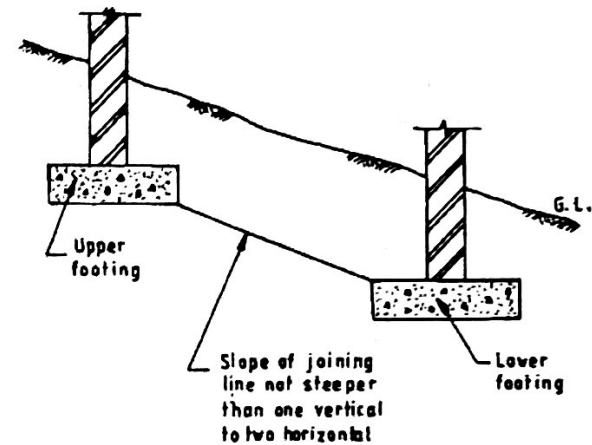
Foundation at Different Levels

In the case of footings on granular soil, the distance between the footings should be such that a line drawn between the lower adjacent edges of the footings shall not have a slope steeper than one vertical to two horizontal as shown in figure.



Foundation on granular soils

In clayey soils, a line drawn between the lower adjacent edge of the upper footing and the upper adjacent edge of the lower footing shall not have a slope steeper than one vertical to two horizontal as shown in figure.



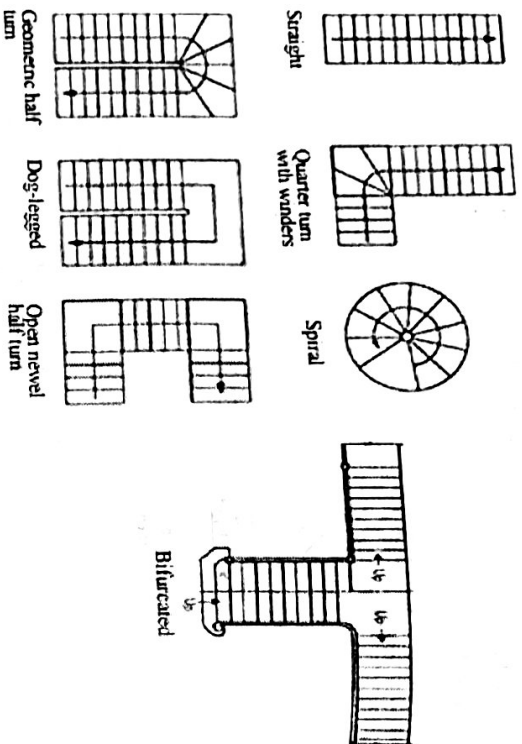
Foundation on clayey soils

Staircase

It is a set of steps leading from one floor to other.

Types of staircase

- Straight flight
- Quarter turn
 - Dog-legged
 - Open newel
 - Geometric half turn
- Bifurcated
- Spiral



1.16 Building services

Water supply service

The minimum water required per head per day depends upon the type of building, eg for residential 100 liters, for office 45 liters etc.

If water is available in the city mains at sufficient quantity throughout the day and pressure is sufficient to lift water up to the highest floor, no storage is required and all fixture could be supplied directly. This is an ideal case and often water has to be stored either in underground tanks, ground water tanks or overhead tanks.

Underground and ground water tanks are necessary to collect water from city water mains during hours of supply if it can't reach the overhead tank due to insufficient pressure.

Requirements of underground tank

- Capacity of the tank must be the net difference between the peak demand and flow during the hours of supply. Provision should be made for supply interruption due to various reasons like power failure or repair work.

- Tanks should be watertight and there should be no leakage or ingress of subsoil water.
- It should have a minimum clearance of 5 m from sewers, septic tanks, soak pits or oil tanks.
- The overflow water level should be above the surrounding ground level to prevent surface water to enter the tank.
- The top slab, walls and base should be designed to take the possible traffic load, natural soil pressure from sides, bulging pressure from the base when empty and water pressure when full.

Requirements of ground water tank

- It should be watertight and constructed with non-corrosive and non-toxic material.
 - It should have a vent pipe for ventilation as well as for prevention of negative pressure when water is drawn out from the tank.
 - It should have an overflow pipe to indicate the overflow of water from the already full tank.
 - It should have a scour / washout pipe with a plug at the lowest point so that it can emptied easily when needed.
 - It should be strong to take the water pressure when full and the negative pressure within the tank when water is drawn out.
 - It should have at least one manhole 450 mm X 450 mm for access and repairs.
- Overhead tank is required to ensure constant supply for domestic use and flushing purpose.

Requirements of overhead tank

- The tank must be clear off the terrace level to avoid overloading the structural slab, leakage and make easy maintenance.
- Tanks must be protected against corrosion from water by painting on the inside and the outside.
- Lightning arresters must be provided on the top of the tanks in high rise buildings.

Principals of house drainage

- a) The lavatory blocks should be so located that the length of drainage line is minimum.
- b) The drainage pipes should be laid by the side of the building rather than below the building.
- c) All drains should be aligned straight between successive inspection chambers. Sharp bends and junctions shall be avoided beneath chambers.
- d) The slope of the drains should be sufficient to develop self-cleansing velocity.
- e) The size of the drain should accommodate maximum possible discharge.
- f) The discharge system must have enough number of suitably located traps. Traps are depressed or bent fittings which always remain full of water thus maintaining a water seal, also preventing the passage of foul gas through.
- g) All connections must be water-tight.
- h) The house drain should be disconnected to the public sewer by the provision of an intercepting trap. It must be ensured that the public sewer is deeper than the house drain.
- i) Rain water drains should be drained directly into the street gutters from where it is carried to storm water drain.
- j) All materials and fittings of the drainage system must be hard, strong and resistant to corrosive action.
- k) The entire system should be designed in such a way that there is no possibility of the formation of air locks and siphonage.
- l) The entire drainage system should have proper ventilation from the starting point to the finishing end.

Water disposal systems / Collection systems**a) Single stack system**

It is the simplest system. All waste matter from baths, sinks, etc., as well as foul matters from the water closet are discharged in one single pipe, called the soil and waste pipe. This pipe terminates as the vent pipe at its top, and no separate vent pipe is provided. It is simple and economical.

b) Two pipe system

It consists of two independent discharge pipes one of which conveys soil excreta directly to the drain and the other conveys waste water to the drain through trapped gully. The discharge from water closet is connected to the soil pipe while the discharge from baths, sinks, lavatory basins are connected to waste pipe. All the traps are completely ventilated by providing separate ventilating pipes. Thus, four pipes are required.

c) One pipe system

It consists of one main pipe which conveys waste from wash basin, baths, sinks, soil pipes to the drainage system. This system is costlier than single stack system.

d) Single stack system partially ventilated

This is the modified form of the single stack system and one pipe system. In this system, the waste from water closet, basins, sinks etc. is discharged into one common soil and waste pipe. In addition, a relief vent pipe is also provided which provides ventilation to the traps of water closets. The traps of basins etc. are not directly connected to the vent pipe.

Septic tank and soak pit

A septic tank is a horizontal continuous flow sedimentation tank in which sewage moves very slowly. It serves two purposes. First is the deposition of the settling solids in sewage by sedimentation and second is the partial or complete digestion of the sludge prior to its disposal. The effluent from the septic tank is discharged either into soak pit or below ground level through open jointed agricultural drains so that the effluent gets absorbed in the soil. The sludge which is deposited in the bottom is cleaned periodically, once in 6 to 12 months. A vent pipe is provided for the escape of gases.

Soak pit is a covered pit dug in the ground, in which effluent from the septic tank is discharged. It is generally dug in pervious soil. Pits are lined by bricks, stone or concrete blocks if the inner volume is kept empty and unlined except masonry ring at the top, if the inner volume is filled with stone and brick aggregates. However, in some soak pits, the sewage is directly discharged. The water in the accumulated

sewage is soaked by adjoining pervious soil while the sludge is digested in the pit. Such soak pits are called sludge soak pits.

Ventilation

It is the supply of fresh outside air into an enclosed space or the removal of inside air from an enclosed space. It is needed to prevent accumulation of carbon dioxide, dust, odor, smoke and allow air movement freely.

Functional requirement of ventilation

a) Air movement

Air change per hour is the volume of outside air allowed in the room per hour compared to the volume of the room. If the rate of air change is less than one per hour there will be no ventilation while if the rate of air change is more than sixty per hour it will cause discomfort because of high air velocity.

b) Quality of air

Ventilating air must be free from odor, impurities, organic, inorganic dust and unhealthy fumes of gases like CO_2 , CO and SO_2 .

c) Humidity

Relative humidity is the ratio of amount of water vapor in the air to the amount of water vapor if the air was saturated at that temperature. It should be within 33 to 70 % at 21°C .

d) Effective temperature

It is desirable that the incoming ventilation air should be cool in summer and warm in winter. Effective temperature must be around 20°C in winter and 22°C in summer.

Air-conditioning

It is defined as the process of treating air so as to control simultaneously its temperature, humidity, purity and distribution to meet the requirements of conditioned space.

Purpose of air-conditioning

- a) It helps in maintaining health, comfort and convenience of occupants of building.

- b) It helps in improving quality of products in certain industrial processes such as artificial silk, cotton cloth etc.
- c) It provides comfort and activeness in shops, banks, offices and theatres.

Methods of thermal insulation

- a) Exterior walls should be thicker to impart insulation against heat and cold.
- b) Cavity walls should be constructed because the hollow space between the two leaves acts as an insulating medium.
- c) The building should be provided with chajjas, canopy, weathersheds, verandah, trees, garden to achieve heat insulation.
- d) In construction of walls, roofs, floors, heat insulation materials like slag wool, light weight concrete, quilts, foamed slag aggregate should be used to fill the air spaces in construction materials.

Electrification

Electric power is generally bought from nearby utility and often supplemented for emergency purposes by power from batteries or a generating plant on the site. Purchased power is brought from the power lines connected to the generating source to an entrance control point and a meter in the building. From there, conductors distribute electricity throughout the building to outlets where the power can be tapped for lighting, heating and operating electric devices. In addition to conductors and outlets, an electrical system also incorporates devices and apparatus for controlling electric voltage and current and for earthing.

Lintel, sill and weathershed

Window sills are provided between the bottom of the window frame and the top of the wall below.

Lintel is provided above the openings of windows, doors and ventilators in the wall to support the weight of wall above the openings.

Weathershed or chajja is a structure combined with lintel to protect doors, windows or ventilators from rain, wind, sun, etc.

Escalator and elevator

Escalator is an electrically operated staircase to move from one floor to another.

Elevator is a moving platform which allows movement from floors to floors in a building.

1.17 National building code

Hierarchy and application of building codes

Type of code	Purpose
a) International State-of-Art Applicable code: NBC 000	This particular code is applicable to large building structures. The structure should comply with existing international state-of-the-art building codes
b) Professionally Engineered buildings Applicable codes: NBC 101-114, NBC 206, NBC 207, NBC 208	Buildings designed and constructed under the supervision of engineers, buildings with plinth area more than 1000 sq. ft., buildings with more than 3 stories, span more than 4.5 meters and buildings with irregular shape.
c) Mandatory Rules of Thumb Applicable codes: NBC 201, NBC 202, NBC 205	Buildings with plinth area less than 1000 sq. ft., less than 3 stories, span less than 4.5 m, regular buildings designed and constructed by technicians.
d) Guidelines for Remote Rural Buildings (Low strength masonry / earthen buildings)	Buildings constructed by masons in remote area not more than 2 stories.

Procedure for implementation of building code in Nepal

The building code was approved by the government of Nepal on 28th July, 2003. Department of Urban Development and Building Construction under the ministry of Urban Development was recognized as the lead agency for the implementation of Nepal National Building Code (NNBC) and the Building Act. The implementation started with compliance of the Building Code to government buildings, at first covering the construction of health buildings, school buildings as well as reconstruction buildings built through Ministry of Peace and Reconstruction. High level awareness has been created among small contractors, masons and dwelling owners through campaigns and publications. But still, issues of successful implementation prevails. So, the following procedures shall be followed:

- It is essential to first resolve the policy related issue so as to create a social environment for the building code. For this, academic awareness about code implementation must be initiated in engineering and architectural institutions or trainings must be provided through Nepal Engineering Council for licensing structural engineers.
- The second issue is activity related to support the local authority. Technical support must be provided to the municipal team to make them able to check and monitor implementation of the NNBC provision.
- The third issue is awareness related. Use of leaflets, pamphlets and participation in different symposiums, conferences and media coverage are some of the approaches to increase awareness of the entire stakeholders starting from client to masons, junior technicians, engineers and architects. Such events should be more frequently held and publicized for wholesome participation.

1.18 Development control system in municipalities in Nepal

Development control system is a system of town and country planning through which local government regulates land use and new buildings. The subsequent development is granted or refused with reference to the development control system as a prime consideration. The system includes promoting energy efficient

transport facilities, road proposals and road safety, ensuring adequate supply of land for housing and other uses and safeguarding important landscapes or sites of historic importance.

In around 1970s, land use plan for all five regional centers were prepared and a detailed physical development plan of government's institutional area were made and implemented. Similarly few towns were established in Terai by clearing some forest lands. Attempts were also made to implement a physical development plan in Kathmandu valley but it could not materialize due to lack of political commitment. During the same time, two sites and services projects were implemented in the valley. Besides these events, land use regulation is no more practiced in Nepal; land is mostly developed by individual's decision and the development pattern is mixed, residential cum commercial. The only basis of development control in municipalities is by the use of building bye-laws. Enforcing building codes, apartment ownership acts and repair of historical buildings are a few tasks performed in municipal level. Besides these, two local area planning measures-land pooling and guided land development programs have been widely implemented in Kathmandu valley. These are land readjustments processes in which land owners compromise a portion of their land to get access to infrastructures and services.

1.19 Maintenance and repair of buildings

Assessment of building damage

The assessment of building damage must be done before carrying out repairs or strengthening. Before commencing any repairs, it is important to:

- Determine the materials which have been used in the damaged building.
- Carry out a detailed foundation check.
- Carry out a detailed structural assessment of the damaged building with particular attention to vulnerable elements of the structure.

This should be assessed by a qualified structural engineer. It should be noted that both non-structural and structural repairs might be required to a building. The priority repairs should be of the

structural components before embarking on any non-structural repairs (cracked slabs, falling plaster from walls and ceilings, rebuilding of parapets etc).

There is absolutely no point carrying out repairs to a building if the foundations have failed or the ground can no longer support the damaged building. Repairs to damaged foundations can be costly and difficult to instigate and hence a fine line may exist between demolishing the building or continuing with the repair.

Moreover, the site can become dangerous. In fact, earthquakes may cause failure of soft or loose ground whilst hillsides or sloping ground may become unstable. Whole towns and villages may be affected and although a building may appear safe for repair, near the foot of the slope or on it, further slope failures could be triggered by relatively small aftershocks or another future earthquake. Buildings in such terrain will require specialist advice for the stability of the whole area. No repairs to buildings should take place until such advice has been obtained.

Retrofitting and its advantages

Retrofit strategy refers to any technique for increasing the strength, stiffness and ductility of the members or of the whole building. The possible intervention options need to be selected based on the building typology and the expected performance of the building after retrofitting. The advantages of retrofitting of the structure over reconstruction are:

- The involved cost for retrofitting is always less than that for rebuilding.
- It takes considerably less time than demolition and new design approach.
- Retrofitting does not disturb regular function of the structure. The internal circulation pattern and functional relations of the building is less disturbed.
- It involves only additions and jacketing to elements, thus, disposal of debris and scrap material is avoided.
- It has high reliability provided proper calculation of loads and connections is done.

Methods of retrofitting for masonry buildings**a) Jacketing**

This method is adopted on buildings constructed with a material that is heavy, weak and brittle. It helps to basket the wall, hence improve its shear strength and ductility. This method also improves integrity and deformability. Main improvements in different structural elements of the building by this method are as follows:

Walls:

To improve strength, deformability and to reduce risk of disintegration, delamination of walls resulting in total collapse of the building, thin reinforcement concrete jacketing of all the walls is done. For this, two steel meshes should be placed on either side (or one side of the wall) and both the meshes should be connected by some steel bar connectors passing through the wall. The thickness of the added concrete should be about 40 to 50 mm. The concrete used ought to be a micro-concrete i.e. concrete with small aggregates. Selection of one-side jacketing or two-side jacketing depends on the analysis results.

Floors:

If the floor is flexible, bracing of the floor elements with steel or timber sections and tying up the floor elements with walls should be done to improve stiffness of the floor system and to obtain integrity between walls and floor.

Roof:

If the roof is flexible, similar to floor, bracing of the roof elements with steel or timber sections and tying up the roof elements with walls should be done to improve stiffness of the roof system and to obtain integrity between walls and roof.

b) Splint and bandage

The splint and bandage system is considered as an economic version of jacketing where reinforcing bars are provided at most critical locations, wherever stress concentration can develop. Splints are vertical elements provided at corners, wall junctions and jambs of openings in the external faces of the building. The objective is to

provide integrity in vertical direction. Bandages are horizontal elements running around all the walls to integrate them together thereby preventing potential out-of-plane collapse of walls. In addition, openings are also surrounded by splints and bandages to prevent initiation and widening of cracks from their corners. Splints are provided on external face only whereas bandages could be provided on both the faces of the walls just at the lintel, eaves and sill level. This method is inferior to jacketing. The strengthening of floor and roof is done in the same way as in jacketing.

c) Bolting / Pre-stressing

A horizontal compression state induced by horizontal tendons is used to improve the shear strength of in-plane walls. This also considerably improves the connections between orthogonal walls. The easiest way of affecting the pre-stressing is to place two steel rods on the two sides of the wall and strengthening them by turnbuckles. These are done at two levels of each storey- lintel level and just below the floor and roof structure. This method improves the earthquake resistance of the building and will delay the collapse, but it is still much inferior to the jacketing or split and bandage in terms of increasing safety. This method is cheaper and will be effective for small and simple buildings.

d) Confinement with reinforced concrete elements

Confinement with reinforced concrete elements (beams and columns) make the existing masonry act as confined masonry in the sense that reinforced concrete elements are inserted surrounding the wall panel or in the middle of the long wall, allowing the entire wall, or its portion, to act as a truss element, where the struts are inclined strip of unreinforced masonry. In this way, brittle and non-ductile wall becomes more ductile and its load carrying capacity increased several times with added confinement of the reinforced concrete elements. It is more suitable for buildings of one to three storey with monolithic reinforced concrete slab and horizontal bands over the load bearing walls at the lintel level. However, implementation of this method of retrofitting is more complex and needs special improvements for foundation also.

e) Base isolation

In this method, the superstructure is isolated from ground motion by introducing a flexible layer between the structure and the ground. Base isolation devices could be laminated rubber bearing, laminated rubber bearing with lead core, sliding bearing or friction pendulum devices. Base isolation modifies the response characteristics so that the maximum earthquake forces on the building are much lower. The seismic isolation eliminates or significantly reduces not only the structural damage but also non-structural damage and enhances safety of the building content and architectural components. This technique is usually employed for buildings with historical importance and critical facilities and is quite expensive as compared to other methods.

f) Use of FRP (Fiber reinforced polymer)

Seismic resistance of masonry buildings improve significantly by using glass or carbon FRP strip on walls. Strengthening with FRP is a new approach. Both flexural and shear capacity of masonry walls can be enhanced by applying thin films of glass or carbon FRP to the exterior surface of the wall. Even though the materials used in FRP are relatively expensive as compared to the traditional strengthening materials such as steel and concrete, the labor, equipment and construction costs are often lower. It is a promising technique since its application is more easy and rapid with minimum disturbance to the occupants. Application of FRP, with care, provides significant increase in lateral strength but it does not provide as much ductility as the RC walls would provide, because of the brittleness of the material. For effective use, a firm anchorage should be provided between FRP and the wall panel.

Methods of retrofitting for reinforced concrete buildings

a) Reinforced concrete jacketing

This method involves addition of a layer of concrete with longitudinal bars and closely spaced ties on existing structural elements. The jacket increases both the flexural strength and shear strength as well as ductility of the column and beam. This method also improves integrity and deformability. Main improvements in different structural elements of the building by this method are as follows:

Columns:

The jacketing not only increases the flexural strength and shear strength of the column but also its ductility. The thickness of the jacket also gives additional stiffness to the concrete column. Since the thickness of the jacket is small, casting self-compacting concrete or the use of shotcrete are preferred to conventional concrete. During retrofitting, it is preferred to relieve columns of the existing gravity loads as much as possible by propping the supported beams.

Beams:

Beams are retrofitted to increase their positive flexural strength, shear strength and the deformation capacity near the beam-column joints. The lack of adequate bottom bars and their anchorage at the joints needs to be addressed. Usually the negative flexural capacity is not enhanced since the retrofitting should not make the beams stronger than the supporting columns. The strengthening involves the placement of longitudinal bars and closely spaced stirrups.

b) Addition of reinforced concrete shear walls

Adding shear walls is one of the most popular and economical methods to achieve seismic protection. Their purpose is to give additional strength and stiffness to the building and could be added to existing and new buildings. They are positioned after careful planning and judgment by the structural engineer as to how they would affect the seismic forces in particular building. However, it is desired to ensure an effective connection between the new and existing structure.

c) Steel bracing

In this method, diagonal braces are provided in the bays of the building. Diagonals stretch across the bay to form triangulated vertical frame and as triangles are able to handle stresses better than a rectangular frame, the structure is also supposed to perform better. Braces can be configured as diagonals, X or even V shaped. Braces are of two types, concentric and eccentric. Concentric braces connect at the intersection of beams and columns whereas eccentric braces connect to the beam at some distance away from the beam-column intersection. Eccentric braces have the advantages that in case of buckling the buckled brace does not damage beam-column joint.

d) Base isolation

In this method, the superstructure is isolated from ground motion during earthquake shaking by using flexible layer between the structure and the ground. This flexible layer or isolators are introduced individually beneath column support, while in masonry building a flexible layer is introduced throughout the wall stretch at base.

e) Use of FRP

Seismic resistance of frame buildings can be improved significantly by using fiber reinforced polymer overlays on RC elements of the building. It is a new approach. FRP is light weight with high tensile strength and has a major advantage of fast implementation. This method could be effectively used to increase strength and stiffness of RC frames. The effectiveness is strongly dependent on the extent of anchorage between FRP strips and the frame.

1.20 Principles of low cost construction techniques

a) Energy efficiency

Energy can be conserved by optimum orientation of the building. Natural lighting, heating and ventilation are key to energy efficiency. The building should be so located that there is maximum transfer of solar energy in the winter and minimum transfer of solar energy in the summer. Similarly, openings should be planned appropriately to allow cross-ventilation and therefore, continuous circulation of air.

b) Materials and resources

Materials should be locally available, minimally processed and renewable without significant environmental and energy implications. This results in low cost for extraction and transportation of the materials. Cost can be saved by using hollow blocks in the façade and the partitions, soil cement blocks in the walls, timber stairs, cast iron rails, steel frames in doors and windows, plywood formworks for concrete elements and also by the use of timber and straw for single storey building. The cost can be greatly reduced by selecting finishing items like sanitary, electrical, paints, floor finishes economically.

c) Water efficiencies

Water recycling techniques and rain water harvesting must be encouraged. This is a green building technique which fulfils the required water demand thus eliminating the need to spend money for the purpose.

d) Innovation

Innovative design is crucial for low cost construction. Structurally, the load bearing elements can be rationally designed to reduce their size with an overall concept of minimizing the total weight of the building. Detailed planning is required to disallow wastage of materials due to demolition of unplanned components of the house. Cost reduction can also be achieved through the use of filler slabs which are normal RCC slabs where the bottom half concrete portions are replaced by filler materials such as bricks, tiles, cellular concrete blocks, etc. These materials are placed in such a way that the structural strength is not compromised while replacing the unwanted and non-functional tension concrete.

1.21 Current building norms for estimating and costing**Norms for estimation of building works**

a) Earthwork in excavation

Earth is excavated for foundation trenches to the exact depth and width of foundation with vertical sides and bottom levelled both longitudinally and transversely. The quantity of earthwork is calculated in cubic meters accurate to the nearest 0.01 cum. Measurement for payment will be limited to the lines, grades, slopes and dimensions shown on the drawings or as determined by the engineer. All required and accepted excavation shall be measured from its original position to the final cross-sections of the completed work.

b) Earthwork in filling

1. Foundation filling

The volume of earthwork for foundation filling can be estimated as some fixed percentage of the volume of earthwork in excavation; the percentage depends on the type of foundation.

2. Plinth filling

The length and breadth of plinth are measured excluding plinth offset from the room or verandah. The depth of filling is estimated from the ground level up to the floor structure.

For payment, measurement shall be based first in cubic meters of loose volume of accepted works with 35% deduction for voids. The measurement is made at the disposal site.

c) Brick soling

It is measured to the nearest 0.01 sq. m. multiplying the length and breadth of the trench. Payment is done as per accepted unit rate of the measured area.

d) Concrete in foundation

It is measured in cubic meters by multiplying the length, breadth and depth of concrete. Payment is done as per accepted unit rate of the entire volume of concrete works.

e) Masonry work in foundation and plinth

All volumes are measured to the nearest 0.01 sq. m. multiplying the length, breadth and height of walls. Deduction for opening is not required since there aren't any openings.

f) DPC

It is a layer of damp proof course laid in between the plinth and superstructure walls to prevent the rise of water by capillary action from the ground. It is measured in sq. m. multiplying its length and breadth stating its thickness.

g) Masonry work in superstructure

It is measured in cubic meters for one brick wall considering completely solid, then deductions are made for openings and lintel. Nothing shall be paid extra for the openings. However, no deductions shall be made for areas less than 0.1 square meter, bearing of lintels, beams, girders and holdfasts. For half brick wall, length and height are multiplied to get brickwork in sq. m. Rate shall be as per approved and shall be inclusive of necessary scaffolding, watering, cutting of bricks, curing, vertical and horizontal reinforcement in brickwork, materials and labor.

h) Formwork

It is measured in square meters actually in contact with the finished face of the concrete. No deduction is made in the measurement for openings, pipes, ducts and the like, provided that the area of each is less than 0.5 square meters. Formwork required for lean concrete to form construction joints and shear keys shall not be measured and the costs shall be included in the rates of the other work. Formwork to contraction and expansion joints shall be measured in square meter on one face only and the rate shall include the cost for forming recesses for sealant and channels for grout. Payment is done as per contract unit rate. The rate shall include the cost of transportation, erection of supports, fillets and chamfers 75mm and less in width, bolts, ties, striking and removing the forms and any remedial work that may be required.

i) Steel work

Tor steel is commonly used and steel work is measured in quintals including binding and bending in position. For estimation purpose in building works, steel reinforcement is calculated as a fixed percentage of the reinforced concrete volume as 1.5% for load bearing structures, 1.7% to 1.75% in normal buildings and 1.8% to 1.9% in important buildings.

j) Wood work

For frames, quantity is measured to the nearest 0.001 cubic meters. For shutters, it is measured to the nearest 0.01 sq. m. by multiplying the height and breadth, stating thickness in description.

k) Flooring

It is measured in sq. m. for a specified thickness measured from wall to wall exclusive of any finishing. Nothing extra shall be admissible for small areas and corners and work in any shape. No deductions shall however, be made for protruding or independent columns occurring in the floors, door frames embedded in floor or any other part provided that the area does not exceed 0.1m^2 for each.

Different varieties of flooring option are available in current practice. But, there are specific places for a particular type of

flooring to be used. IPC flooring (screeding and punning work) is used in stores, terraces and rooms in which carpet will be spread. Tiles are used in bathroom floors and walls, in corridors and waiting lobbies. Even for terrace floors, terrace tiles can be found in the market which is gaining popularity. Mosaic is used in lobbies, staircases, waiting areas and halls. However, it is less preferred nowadays due to the difficulty in finishing the floor. Granites and marbles are used in kitchens, countertops, parapet tops, waiting lobby and staircase. In operation theatre of hospitals, epoxy flooring is used.

l) Concreting in roof

It is measured in sq. m., the average consolidated thickness is described. The concreting of slab, beam, columns, shear walls and water tanks should not be done in grade lesser than M20 (1:1.5:3).

m) Plastering

Measurement is done in sq. m. before plastering and deduction for openings is made. No deduction or addition shall be made for joists, posts, steps, etc. and openings not exceeding 0.5 sq. m. each. For openings up to 3 sq.m. and when both faces are plastered, deduction shall be made for one face only and no additions shall be made for jambs, sills, etc. For openings exceeding 3 sq. m., deduction shall be made on each face but addition should be done for jambs, soffits and sills. Payment is made as per approved rates.

For estimation purpose, it is most appropriate to estimate the wall plaster in 1:4 cement mortar 12.5mm thick and the ceiling plaster in 1:3mm cement mortar 12.5mm thick. In case of stone masonry walls 20mm thick cement plaster is required due to the irregularity of the surface.

n) Painting

It is measured in sq.m. and surfaces are taken flat not girthed. Multiplying factors are used for uneven surfaces like 1.5 for collapsible gate. Payment shall be done at accepted rate. The rate

shall include for specified coats inclusive of materials, labor, scaffolding all complete.

The inside of the building can be painted with varied shades and quality of distemper paint or plastic emulsion paint whereas the outside is painted with weather coat which is also available in different quality. For metals like grills, iron gates, metal trusses and for wood frames, enamel paint over a metal or wood primer must be estimated.

Norms for costing of building works

The costing of a building requires the completion of quantity estimation of all the items of civil, sanitary, electrical as well as provisional works. An abstract of cost is prepared for each work by computing the total cost of all items of that work using the formula- Total cost of an item = Quantity of the item X Rate of the item. The rate of an item is based on the standard norms for that item as set by the government, which is updated only if corrections are sought in the long run, and the district material rate which is revised every fiscal year. Finally, a summary of cost is prepared in the following format to conclude the costing of a particular building work.

SUMMARY OF COST	
(a) Civil works	
- For building construction	
- For site development	
(b) Sanitary works	
(c) Electrical works	
(d) Provisional Sum	
(e) Total estimate (a+b+c+d)	
(f) Contingency (5% of e)	
(g) Total estimated amount (e+f)	
(h) VAT (13% of g)	
(i) Grand total	

Section - B

STRUCTURAL DESIGN AND ANALYSIS

2.1 Design of RCC footings, columns, slabs, beams

Design steps for RCC square footing with uniform thickness

Step (i) Size of footing

Let the axial load transferred by the column be P

Add 10 % of P as self-weight of footing.

Load on soil = $P + 0.1 P = 1.1 P$

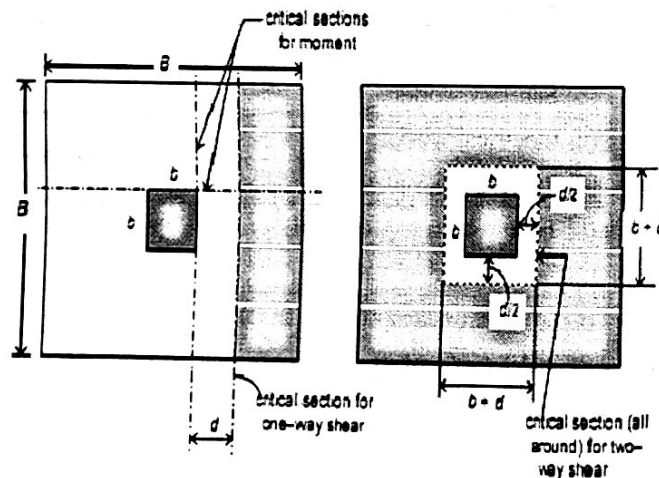
Area of footing required (A) = $1.1P / \text{Safe bearing capacity}$

Size of footing (B) = $\sqrt{A}$. Round this off to the next higher multiple of 100mm.

Step (ii) Determine the soil reaction for the factored load

$$q_u = P_u / A = 1.5P / A \quad (\text{must be } < 1.5 \text{ SBC})$$

Step (iii) Determine the minimum depth required from the consideration of:



a) Bending moment

The critical section from the consideration of bending moment is at the face of the column.

Bending moment at critical section is,

$$M_u = B \times q_u \times \frac{(B-b)}{2} \times \frac{1}{2} \times \frac{(B-b)}{2}$$

The limiting bending moment is

$$M_{u, \text{lim}} = 0.148 * f_{ck} * B * d^2 \text{ for mild steel (Fe 250)}$$

$$M_{u, \text{lim}} = 0.138 * f_{ck} * B * d^2 \text{ for torsteel (Fe 415)}$$

$$M_{u, \text{lim}} = 0.133 * f_{ck} * B * d^2 \text{ for TMT bars (Fe 500)}$$

b) Minimum depth from one way shear

The critical section for one way shear is at a distance of ' d ' from the column face.

Design shear is,

$$V_u = q_u \times B \times \left(\frac{B-b}{2} - d \right)$$

$$\Gamma_u = \frac{V_u}{B \times d}$$

The value of Γ_u should not be more than the critical shear stress in concrete.

$$\therefore q_u \times B \times \left(\frac{B-b}{2} - d \right) = \Gamma_c * B * d$$

However, at this stage Γ_c is not known. So, Γ_c is assumed as the value corresponding to 0.2% steel for a particular grade of concrete (obtained from Table 19 of IS 456:2000).

c) Two way shear

The critical area is the whole portion at a distance of $d/2$ from the column face.

Punching force is given by,

$$S = q_u * [B^2 - (b+d)^2]$$

Area resisting the punching force is, $A = 4 * (b+d) * d$

Punching shear stress (Γ_p) = S / A

Permissible value (Γ_{per}) = $0.25 \sqrt{f_{ck}}$ where, unit must be in N/mm^2 .

Step (iv) Determine the area of reinforcement required

$$M_u = 0.87 * f_y * A_{st} * d * \left(1 - \frac{A_{st} f_y}{B d f_{ck}}\right)$$

Using bars at least 10 mm in diameter, spacing of bars is

$$S = \frac{\pi \phi^2}{4 A_{st}} * B$$

Provide same spacing both directions.

Step (v) Check for development length

Sufficient bond length must be available from the face of the column.

$$\text{Required } L_d = \frac{0.87 f_y \phi}{4 \Gamma_{bd}}$$

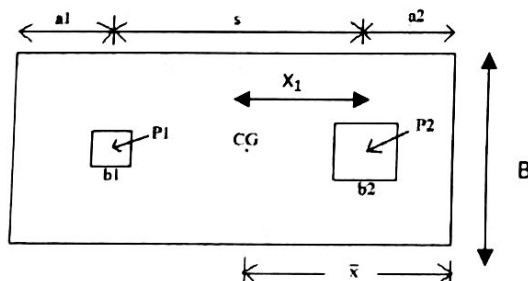
Design steps for combined footing of two square columns

Combined footing is generally provided when individual isolated footings of two adjacent columns overlap each other. This happens generally when a column is very close to the property line thus requiring an eccentric isolated footing that is more likely to overlap with the isolated footing of the adjacent column.

Step (i) Length of footing

Taking moment of load about the center of column b_2 ,

$$x_1 = \frac{P_1 \times s}{(P_1 + P_2)} \text{ where } P_1 \text{ and } P_2 \text{ are the column axial loads.}$$



Distance of CG from the right end = $\bar{x} = x_1 + a_2$

Length of footing is, $L = 2 * \bar{x}$.

Step (ii) Size of footing

Taking 10% as self-weight of footing,

$$\text{Area of footing} = \frac{1.1(P_1 + P_2)}{SBC}$$

So, width of footing (B) = Area / L

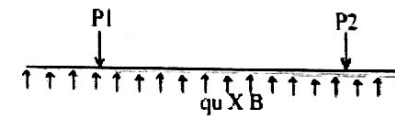
Step (iii) Net upward pressure due to factored load

$$P_{u1} = 1.5 P_1$$

$$P_{u2} = 1.5 P_2$$

$$\text{Net upward pressure } (q_u) = \frac{P_{u1} + P_{u2}}{A_{\text{adopted}}} \text{ (must be } < 1.5 \text{ SBC)}$$

Step (iv) Draw SFD and BMD for the line diagram of load in longitudinal direction.



Obtain the point of zero shear from the shear force diagram and compute the maximum negative bending moment which is the BM at that point.

Step (v) Depth of footing

$$M_{u, \text{lim}} = 0.148 * f_{ck} * B * d^2 \text{ for mild steel (Fe 250)}$$

$$M_{u, \text{lim}} = 0.138 * f_{ck} * B * d^2 \text{ for torsteel (Fe 415)}$$

$$M_{u, \text{lim}} = 0.133 * f_{ck} * B * d^2 \text{ for TMT bars (Fe 500)}$$

Taking the maximum negative bending moment, determine the depth required. Increase the value by 100% and adopt as the overall depth of footing because shear is more critical in footing and depth from moment consideration is never enough. Reduce the effective cover in the overall depth to obtain the effective depth of footing.

Step (vi) Provide main negative longitudinal reinforcement at the top based on the value of maximum negative bending moment. Compute the percentage of steel provided which shall be used to check for one way shear.

Step (vii) Check for one way shear

The critical section for one way shear is at a distance of 'd' from the column face (both columns must be considered individually).

Design shear V_u is obtained from the SFD,

$$\Gamma_u = \frac{V_u}{B * d}$$

The value of Γ_u should not be more than the critical shear strength in concrete obtained from Table 19 of IS 456: 2000, for the percent of steel computed in preceding step and the adopted grade of concrete.

Step (viii) Check for two way shear

The critical area is the whole portion at a distance of $d/2$ from the column face (both columns must be individually checked).

Considering column b_1 as critical, punching force is given by,
 $S = P_1 - q_u * (b_1 + d)^2$

Area resisting the punching force (if column b_1 is more critical) is, $A = 4 * (b_1 + d) * d$

Punching shear stress (Γ_p) = S / A

Permissible value (Γ_{per}) = $0.25 \sqrt{f_{ck}}$

Step (ix) Provide positive longitudinal reinforcement at the bottom based on the value of maximum positive bending moment extracted from BM diagram or equation.

Step (x) Transverse reinforcement

Transverse reinforcement is provided at the bottom of the columns in transverse direction forming a band equal to column width plus two times the effective depth of the footing. The equivalent UDL load under individual

columns (i.e., P_1 / B under column b_1 and P_2 / B under column b_2) is computed. The critical bending moment is the value at the face of the column in transverse direction. For each column, reinforcement is designed based on the critical BM of its case.

Step (xi) Nominal reinforcement

It is provided in transverse direction at the top and at the bottom where transverse reinforcement is not applied (i.e., at places other than the band). The nominal percentage of steel is taken as 0.12%.

General design considerations of raft

a) Dimensional parameters

The size and shape of the foundation adopted affects the magnitude of subgrade modulus and long term deformation of the supporting soil and this, in turn, influences the distribution of contact pressure. This aspect should be taken into consideration in the analysis.

b) Eccentricity of load

A raft generally occupies the entire area of the building and often it is not feasible to proportion it coinciding the centroid of the raft with the line of action of the resultant force. In such cases, the effect of the eccentricity on contact pressure distribution should be taken into consideration.

c) Properties of the supporting soil

Distribution of contact pressure underneath a raft is affected by the physical characteristics of the soil supporting it. Considerations must be given to the increased contact pressure developed along the edges of the foundation on cohesive soils and the opposite effect on granular soils. Long term consolidation of deep soil layers should be taken into account in the analysis. This may necessitate evaluation of contact pressure distribution both immediately after construction and after completion of the consolidation process. The design must be based on the worst conditions. The following points need more attention:

- In granular soils, the ultimate bearing capacity of rafts is generally very large. For rafts placed at considerable depth (for example basement rafts), the possibility of punching mode of failure should be investigated. The influence of soil compressibility and related scale effects should be assessed.
 - For rafts on cohesive soils, stability against deep seated failures should be checked.
 - In cohesive soils, the effect of long term settlement should be taken into consideration.
 - Soil-structure interaction becomes significant in foundations resting of soft soils.
- d) Heavy vibration loads
Foundations subjected to heavy vibratory loads should preferably be isolated by providing a sand box all around or a foam padding.
- e) Sub-soil water pressure
The uplift due to the sub-soil water should be considered in the design. All construction below the ground water level should also be checked for flotation.

Design of columns: Axially loaded

- a) Effective length
The effective length of a column is given by
$$l_{eff} = k * l$$

where, l is unsupported length
 k is a constant that depends on end condition (obtained from Table 28 of IS456:2000)
- b) Determine column size
By assuming 1% steel, obtain the size of column
$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$$

where, $A_c = 99\%$ of A_g
 $A_{sc} = 1\%$ of A_g

Determine the size of square column by, $b = \sqrt{A_g}$. Round off to higher multiple of 50mm.

- c) Check for slenderness ratio
$$l_{eff}/b < 12 \quad \text{Short column}$$

$$l_{eff}/b > 12 \quad \text{Long column}$$

Proceed if it is a short columns; long columns are dealt differently.
- d) Determine eccentricity
$$e_{min} = l / 500 + b / 30$$

If $e_{min} < 0.05 b$, it is an axially loaded column
- e) Determine area of reinforcement
$$A_{sc} = \frac{1}{100} * A_{g, \text{required}}$$
- f) Design lateral ties
Diameter of ties should not be lesser than 5mm or $\phi_{longitudinal} / 4$.
Spacing shall be a minimum of least lateral dimension of column, $16 \phi_{longitudinal}$ or 300 mm.

Design of columns: Axially loaded with uniaxial moment

- a) Check for slenderness ratio
- b) Determine eccentricity
$$e = M_u / P_u$$

$$e_{min} = l / 500 + D / 30$$

If $e > e_{min}$ or $e_{min} > 0.05 D$, it has uniaxial moment
- c) Determine area of reinforcement
Calculate $P_u / f_{ck} b D$, $M_u / f_{ck} b D^2$ and d'/D . Use appropriate chart in SP-16 to get p/f_{ck} . Find the area of bars required from percentage of steel (p).
- d) Design lateral ties
Diameter of ties should not be lesser than 5mm or $\phi_{longitudinal} / 4$.
Spacing shall be a minimum of least lateral dimension of column, $16 \phi_{longitudinal}$ or 300 mm.

Design of columns: Axially loaded with biaxial moment

- Find $M_u = 1.15 * \sqrt{M_{ux}^2 + M_{uy}^2}$. Calculate $P_u / f_{ck}bD$, $M_u / f_{ck}bD^2$ and d'/D . Use appropriate chart in SP-16 for equal bars on all four faces.
- Find the actual 'p' provided and p/f_{ck} provided, determine $M_{ux1}/f_{ck}bD^2$ corresponding to that value, $P_u / f_{ck}bD$ and d'/D using appropriate chart in SP-16. Find M_{ux1} .
- Similarly, for M_{uy1} , determine $M_{uy1} / f_{ck}Db^2$ corresponding to p/f_{ck} provided as in step (b), $P_u / f_{ck}bD$ and d'/D using appropriate chart in SP-16. Find M_{uy1} .
- Determine P_{uz}

$$P_{uz} = 0.45 f_{ck}A_c + 0.75 f_y A_{sc}$$
- Find α_n corresponding to P_u / P_{uz} which can be easily interpolated from the table provided in the code.
- Check interaction formula

$$\left(\frac{M_{ux}}{M_{ux1}} \right)^{\alpha_n} + \left(\frac{M_{uy}}{M_{uy1}} \right)^{\alpha_n} < 1$$
- If the interaction formula is not satisfied, increase p and try again. If the value in the LHS is too less compared to 1, it implies that the section is very conservative and hence it is recommended to slightly decrease the rebar percentage and check again.
- Design lateral ties
 Diameter of ties should not be lesser than 5mm or $\phi_{longitudinal} / 4$.
 Spacing shall be a minimum of least lateral dimension of column, $16 \phi_{longitudinal}$ or 300 mm.

General design procedure for beams

- Identify the critical sections to be designed
- If slab is monolithically cast with beam, decide whether the section is to be designed as rectangular section or as flanged section.
- Fix the dimension of the beam using thumb rule. If the same beam acts as a rectangular section in some portion and as

flanged beam in some other section, overall dimension is to be based on consideration of rectangular section and the same is maintained throughout.

- Determine effective span.
- Determine design moment and design shear
- Design the section for flexure and determine longitudinal bars.
- Design the section for shear and determine the size and spacing of stirrups.
- Check for deflection
- Sketch the details

Design of singly reinforced rectangular beams

- Take the depth as $1/12^{th}$ to $1/15^{th}$ span. Round it off to nearest multiple of 50mm.
- Take the breadth as $1/3^{rd}$ to $1/2^{th}$ of the depth, minimum being 200mm. Round it off to multiple of 50mm. However, 230 mm is also permitted.
- Determine $M_{u \lim}$
- If $M_{u \lim} < M_u$, increase the depth accordingly (Note, M_u and V_u are factored maximum moment and shear values)
- Equating the moment of resistance to bending moment, determine the area of steel required. For this,

$$M_u = 0.87 * f_y * A_{st} * d * \left(1 - \frac{A_{st} f_y}{bd f_{ck}} \right)$$

The above equation is quadratic in A_{st} . It is solved and the number and suitable diameter of bars are determined.

- Design of shear reinforcement
 - Determine nominal shear, $\Gamma_v = \frac{V_u}{b * d}$
 - Find design shear strength of concrete Γ_c using table 19 in IS456:2000.
 - If $\Gamma_v < \Gamma_c$ provide nominal shear reinforcement consisting of 2 legged 8mm (or 6mm) bars at not more than 0.75d or 300mm whichever is less.
 - If $\Gamma_c < \Gamma_v < \Gamma_{c \max}$ design shear reinforcement.
 - If $\Gamma_v > \Gamma_{c \max}$ revise the section.

Design of doubly reinforced rectangular beams

In case of doubly reinforced section design, the depth of beam is known from other considerations. The width can be selected suitably. For the section selected,

- a) Find $M_{u, \text{lim}}$ using the formulae below,

$$M_{u, \text{lim}} = 0.148 * f_{ck} * B * d^2 \text{ for mild steel (Fe 250)}$$

$$M_{u, \text{lim}} = 0.138 * f_{ck} * B * d^2 \text{ for torsteel (Fe 415)}$$

$$M_{u, \text{lim}} = 0.133 * f_{ck} * B * d^2 \text{ for TMT bars (Fe 500)}$$

- b) When $M_u > M_{u, \text{lim}}$, doubly reinforced section is to be designed.
 c) Find A_{st1} required to resist $M_{u, \text{lim}}$, as singly reinforced section. For this,
 $C = T$

$$0.36 f_{ck} b x_{u, \text{lim}} = 0.87 f_y A_{st1}$$

- d) Find $M_{u2} = M_u - M_{u, \text{lim}}$

The moment M_{u2} is the moment of resistance to be provided by compressive steel and additional tensile steel A_{st2} .

$$M_{u2} = 0.87 f_y A_{st2} (d - d')$$

where, d' is the cover to compression steel.

Now, total tensile steel = $A_{st1} + A_{st2}$

- e) From linear strain diagram, we get,

$$\epsilon_{sc} = 0.0035 \frac{x_{u, \text{lim}} - d'}{x_{u, \text{lim}}}$$

where, ϵ_{sc} is the strain in compression steel. Then, find the corresponding stress f_{sc} . For this, use stress strain diagram for steel of Fig 23 in IS 456. Pick the value corresponding to the curve $f_y / 1.15$. Find the area of compression steel A_{sc} required using,

$$f_{sc} A_{sc} = 0.87 f_y A_{st2}$$

Then, select tension and compression bars.

- f) Design shear reinforcement similar to singly reinforced section.

Design of one way slab

- a) Check for ratio of spans
 $l_y / l_x / 2$ (for one way slab)

- b) Determine the depth of slab
 By deflection criteria,

$$l / d \leq \text{Basic value} * F1 * F2 * F3$$

where, Basic value is 7 for cantilevers, 20 for simply supported and 26 for continuous

$F1$ is a factor to account tensile reinforcement and is generally more than 1.25

$F2$ and $F3$ are close to unity

- c) Find the factored moment M_u for 1 m width of slab.
 d) Determine $M_{u, \text{lim}}$ for 1 m wide slab. If $M_u < M_{u, \text{lim}}$, design singly reinforced section. If $M_u > M_{u, \text{lim}}$, increase depth and design singly reinforced section.
 e) Spacing of the main bars must be calculated using,

$$S = \frac{\pi \phi^2 / 4}{A_{st}} * 1000$$

Spacing must not be more than $3D$ or 300 mm. Note that the main bars must be provided along the shorter span.

- f) Check for shear

$$\text{Design shear} = \Gamma_v = \frac{V_u}{b * d} \text{ (Remember, } b = 1000 \text{ mm)}$$

The design strength of concrete is taken as $k_s \Gamma_c$

where, k_s is a factor depending upon slab thickness obtained from Clause 40.2 in IS 456:2000.

Shear reinforcement is avoided in slab so if $\Gamma_v > \Gamma_c$ the slab thickness is increased and redesigned.

- g) Check for deflection
 $l / d \leq \text{Basic value} * F1 * F2 * F3$
 h) Distribution steel

A minimum of 0.12 percent of total cross section for Fe 415 and a minimum of 0.15% of total cross section for mild steel is provided as distribution steel, which is provided along the longer span.

Design of two way slab

- a) Check for two way
 $l_y / l_x < 2$ (for two way slab)
- b) Determine the depth of slab
 If short span is less than 3.5 m and live load less than 3 KN/m², l_x / d ratio is as follows,

	Fe250	Fe415/Fe500
Simply supported	35	28
Continuous	40	32

If shorter span is greater than 3.5 m or LL is greater than 3 KN/m², $l_x / d \leq \text{Basic value} * F1 * F2 * F3$

- c) Find effective length l_x and l_y as obtained from IS 456:2000.
- d) Calculate design moments using coefficients as per condition (Table 26 of IS 456:2000)

$$M_x^+ = \alpha_x^+ * w_u * l_x^2$$

$$M_y^+ = \alpha_y^+ * w_u * l_x^2$$

$$M_x^- = \alpha_x^- * w_u * l_x^2$$

$$M_y^- = \alpha_y^- * w_u * l_x^2$$

It becomes crucial to understand the symbols. M_x and M_y are design moments along X and Y direction respectively. The positive sign indicates sagging moment at mid-span and negative sign indicates hogging moment in the top face of the slab at support locations.

- e) Calculate design shear force

$$V_u = w_u * \frac{r^4}{1 + r^4} * \frac{l_x}{2} \text{ where, } r = \frac{l_y}{l_x}$$

- f) Design reinforcements in both directions

$$M_u = 0.87 * f_y * A_{st} * d * (1 - \frac{A_{st} f_y}{Bd f_{ck}})$$

- g) Check for shear

$$\Gamma_v = \frac{V_u}{b * d}$$

$$\Gamma_v < k_s \Gamma_c$$

where, k_s is a factor depending upon slab thickness obtained from Clause 40.2 in IS 456:2000.

Shear reinforcement is avoided in slab so if $\Gamma_v > \Gamma_c$ the slab thickness is increased and redesigned.

- h) Check for deflection

$$l / d \text{ provided} \leq \text{Basic value} * F1 * F2 * F3$$

- i) Torsional reinforcement at corners

The reinforcement is provided in the form of a mesh extending over a distance of 0.2 l_x beyond the face of the supporting wall. The bars are provided are U-shaped i.e., extending over top and bottom.

2.2 Analysis of structural system in a building

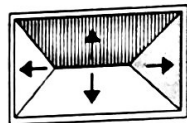
Structural analysis is the determination of the effects of load on physical structures and their components. It involves the computation of structure's deformation, internal force, stress, reactions, accelerations and stability. In a typical reinforced concrete building, the structural system is quite complex. The structure is three-dimensional, comprising of floor slabs, beams, columns and footings, which are monolithically connected and act integrally to resist gravity loads (dead loads, live loads) and lateral loads (wind loads, seismic loads). In order to simplify the analysis, the effects of gravity loads and lateral loads may be considered separately and their results superimposed, after applying appropriate weighting factors (as per code) to give design factored moments.

With the availability of advanced software packages, the modern trend is to let the computer do all the analyses as a black box. However, the results of such analyses are highly dependent on the input data fed into the computer and errors in the input – conceptual or numerical, may lead to disastrous results. In such case, the approximate manual methods of analyses prove to be highly useful as they provide a rough check on the detailed analyses.

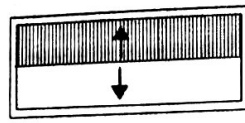
Manual analysis for gravity loads

The load is transferred from slabs in each floor level, to the supporting beams by tributary area method as shown in the figure

below. Triangular load acts on each of the two short span beams, whereas the long span beams are subjected to trapezoidal loads. In case of a one-way slab, the trapezoidal load is generally approximated as a simple rectangular load and the triangular load on the shorter span is deemed negligible. In case there are secondary beams, tributary areas are formed in a similar fashion and the loads from the secondary beams are transferred as concentrated loads to the supporting main beams.



TWO-WAY SLAB



ONE-WAY SLAB

The load on each main beam is shared equally by two supporting columns at respective floor levels. In addition to the gravity loads from the floor slabs, the loads from walls (where applicable) as well as the self-weight of beams and columns should be considered. For preliminary design, all panels may be assumed to be fully loaded with dead loads plus live loads (however, in actual all code-specific load combinations must be considered). A crude estimate of the maximum design moment in a continuous beam may be taken as $6W_u \cdot l / 10$, where W_u is the total factored load on the beam and l its effective span. Similarly, the design shear force may be approximated as $W_u / 2$. Similarly, for columns, loads transferred from adjoining beams in the form of axial compression and unbalanced bending moment are computed. The load in column gets accumulated as it gets transferred to lower floor levels. Particular care must be taken in the exterior columns as they are subjected to significant bending moment (on account to unbalanced beam end moments) in addition to axial forces.

Manual analysis for lateral loads

The code-specific design seismic coefficient, which depends upon the location of site, the natural time period of proposed building, the relative importance of the building and its lateral load resisting mechanism, is computed based on NBC 105 or IS 1893. The seismic weight of each floor level is calculated and summed to obtain the total. The base shear of the building (the product of

design seismic coefficient and total seismic weight) is distributed to each floor based on code provisions. Each seismic force acts along the center of mass of respective floor diaphragm, but is resisted through the center of rigidity which seldom coincides with the former. The torsional moment thus produced and the seismic force at each floor is then distributed to existing moment resisting frames or shear walls in proportion to their stiffness. After reducing the 3 dimensional problem to 2 dimensional frame analysis, the critical bending moments and shear at beams and critical axial compression and moments at columns are worked out using Portal frame method or Cantilever method, which will not be addressed in detail.

The design of the structural elements is done only after combining the design forces due to gravity as well as lateral load consideration, using specified partial load factors and identifying the worst combination at each critical section of the element.

2.3 Design of steel structure

The design of steel structure is based on characteristic values for material strengths and applied loads which takes into account the probability of variations in material strengths and loads acting in the structure. The design should satisfy,

$$\text{Design action} \leq \text{Design strength}$$

$$\text{The design action } (Q_d) = \sum_k \gamma_{fk} * Q_{ck}$$

where, Q_{ck} is the characteristic actions that are not expected to be exceeded with 5% probability during the life of the structure

$$\text{The design strength } (S_d) = S_u / \gamma_m$$

where, S_u = ultimate strength

γ_m = partial safety factor for materials

There are various structural elements in a steel structure which are,

- Tension members
- Compression members
- Beams
- Beam-column
- Column bases and caps
- Brackets

g) Connections

The most important aspect is the design of connections. When steel structures are exposed to loads more than expected, the members deform to absorb energy and remain erect. To ensure the integrity of the structure and load distribution, connections need to be designed with sufficient moment capacity to transfer loads in steel constructions.

Design capacity of bolt

a) Design shearing capacity

$$V_{dsb} = V_{nsb} / \gamma_{mb}$$

where, γ_{mb} = partial safety factor for bolts = 1.25

$$V_{nsb} = \text{nominal shear capacity of bolt} = \frac{f_{ub}}{\sqrt{3}} * (n_n A_{nb} + n_s A_{sb})$$

where, f_{ub} = ultimate tensile strength of bolt

n_n = number of shear planes within threading of a bolt

A_{nb} = Net shear area of bolt

A_{sb} = Sectional area of shank of bolt

n_s = number of shear planes within shank of a bolt

b) Design bearing capacity

$$V_{dpb} = V_{npb} / \gamma_{mb}$$

where, γ_{mb} = partial safety factor for bolts = 1.25

$$V_{npb} = \text{nominal bearing strength of bolt} = 2.5 * k_b * d * t * f_u$$

$$\text{where, } k_b = \text{smallest of } \frac{e}{3 d_0}, \frac{p}{3 d_0} - 0.25, \frac{f_{ub}}{f_u}, 1$$

where, e = end distance

p = pitch

d_0 = diameter of hole

f_{ub} = ultimate tensile strength of bolt

f_u = ultimate tensile strength of plate

d = nominal diameter of bolt

t = least thickness of plates

Advantages of steel structures in earthquake environment

- Durable and light
- All characteristics of structural steel are known, consistent and well understood in terms of engineering.
- High ductility enables steel frame buildings to resist horizontal and vertical loads more than expected, without collapse.
- Minimum risk of error as it is manufactured and controlled at factory.
- Economical repair without large scale disassembly

2.4 Design of timber structure**Design of tension member**

The tensile stress ' f_t ' parallel to the grain should not exceed the design tensile strength parallel to grain ' F_t '.

$$f_t = P / A_n \leq F_t$$

where, P = Axial tensile load

A_n = Net area of section

Design of columns

a) Solid column

It consists of a single piece of timber or pieces glued together to act as a single member.

$$F_c = P / A_g \leq F_c$$

where, P = Axial load on column

A_g = Gross area of column

F_c = design value in compression parallel to grain multiplied by modification factors

b) Built-up column

It consists of individual pieces of lumber joined by mechanical fasteners such as nails, spikes or bolts to act as a single member.

c) Spaced columns

It consists of three elements,

- Two or more individual rectangular wooden members with their wide face parallel

2. Wood blocks that separate the members and one or more points in between
3. Steel bolts through the blocks

Design of beams

Bending:

The usual bending equation $M = \sigma_b * Z$ is used for rectangular beams up to 30 cm deep. For deeper beams, Z is reduced by a form factor k_3 .

$$k_3 = 0.81 * \frac{D^2 + 894}{D^2 + 550}$$

where, D is the depth of beam in cm

For I-beam and box girder, Z is multiplied by form factor k_4

$$k_4 = 0.8 + 0.8 * \gamma * \left(\frac{D^2 + 894}{D^2 + 550} - 1 \right)$$

where, $\gamma = p_1^2 * (6 - 8 p_1 + 3 p_1^2) (1 - q_1) + q_1$

p_1 = ratio of thickness of compressive flange to depth of beam (d_1/d)

p_2 = ratio of total thickness of web to overall width of beam (t_1/t_2)

Shear:

The minimum shear stress is given by,

$$\tau_{\max} = \frac{1.5V}{b * D} \leq \tau_{\text{permissible}}$$

Deflection:

Deflection $\leq$ Span / 240 (Loads taken for calculation of deflection must be twice DL + $\frac{3}{4}$ LL).

Advantages of timber in construction

- a) The construction of timber frame structure is faster than masonry, steel or RCC construction.
- b) Timber is a natural building material. As it ages, it does not break down into environmentally damaging material. Also, it is renewable.
- c) It takes very little energy to convert wood in tree to the timber used in building.

- d) Using timber in buildings stores carbon which would otherwise be adding to greenhouse effect.
- e) Timber is a natural insulator and can reduce energy demands.
- f) Timber structures can be built with a small crew reducing the site labor cost greatly.
- g) Timber is versatile and can be used in a wide variety of ways. It is light and easy to handle.

Disadvantages of timber in construction

- a) Combustibility is a major concern as timber is naturally vulnerable to fire.
- b) There are reserved thoughts regarding timber construction among designers, builders, insurance companies, financial institutions and end users.
- c) Timber frames are designed and manufactured to tight tolerance and require accurate setting out of ground works and other adjoining construction such as chimneys, rising walls and block construction. As a result, these works need to be set out with a high degree of accuracy. Problems arise on a site if agreed tolerance between the required dimensions and the built dimensions are not followed.
- d) Precise skills are required in assembly of members at site to avoid defects such as moisture penetration and structural dis-integrity.
- e) Knowledge of timber structure is still not full-fledged thus resulting in uneconomical designs and high expenses.
- f) Protection of timber panels on site against excessive moisture needs to be monitored separately.
- g) It is unsuitable in rainy areas where timber frames can deteriorate due to excessive exposure to rainfall.

2.5 Design of masonry structure

Masonry buildings are brittle structures and vulnerable to damage under strong earthquake. Ground vibrations during earthquake produce inertia forces at locations of mass in the building. These forces travel through the roof and walls to the foundation. Of the three components (roof, walls and foundation), walls are the most vulnerable to damage. A wall topples down easily if pushed horizontally at the top in direction perpendicular to the plane

(weak direction) but offers great resistance in the direction of the length (strong direction). Horizontal inertia forces developed at the roof transfers to the wall either in the strong or in the weak direction.

Provisions for improving seismic resistance of block and brick masonry

a) Architectural provisions

To ensure good seismic performance, all walls must be joined properly to adjacent walls and tied to the roof and foundation to behave like a box. This can be done by ensuring good interlocking of the masonry courses at the junctions. Similarly, the size of doors and windows must be kept small to ensure smooth flow of forces. The openings should be provided away from the corners so that load can be transferred from one wall to another easily. The tendency of wall to topple in the weak direction can also be reduced by limiting its length to thickness or height to thickness ratio. Walls too long or too tall are vulnerable to shaking in the weak direction.

b) Provision of horizontal bands

Horizontal bands are highly effective in earthquake resistance. There are four types of bands in a typical masonry building namely gable band, roof band, lintel band and plinth band. The lintel band is the most important and must be provided in almost all buildings. This band ties the walls together and creates a support for walls loaded along weak direction from walls loaded in strong direction. It also reduces the unsupported height of the masonry wall and thus improves their stability in the weak direction. Plinth band is provided when there is concern about uneven settlement of foundation soil. Gable band is provided at the top of gable masonry below the purlin and continued with the roof band at the eaves level. It is provided only in sloped roofs. Roof band is provided for sloped roofs as well as for flat roofs made of materials other than RCC.

c) Provision of vertical bands

Embedding vertical reinforcement bars at the corners and junctions of walls and anchoring them in the foundation at the

bottom and in the roof band at the top forces the slender masonry piers to undergo bending rather than rocking. It also delays X-cracking commonly observed during seismic events in case of unreinforced masonry. The vertical bars also protect the wall from sliding as well as from collapsing in the weak direction.

d) Choice and quality of building materials

Bricks or blocks of adequate strength and low porosity should be used and they must be soaked in water before use to minimize the amount of water drawn away from mortar. Masonry units should be stronger than the mortar. Various mortars are available such as mud, cement-sand or cement-sand-lime. Of these, mud is the weakest while cement-sand-lime mortar is preferred. Excessive thickness of mortar is not desirable, generally 10 mm is practiced.

Provision for improving seismic resistance of stone masonry

a) Ensure proper wall construction

The wall thickness should not exceed 450 mm. Round stone boulders should not be used in the construction. Instead, the stones should be shaped using chisels and hammers. Coursed rubble masonry is preferred. Use of mud mortar should be avoided in higher seismic zones. Instead cement-sand mortar of 1:6 or richer and lime-sand mortar 1:3 or richer should be used.

b) Ensure proper bond in masonry courses

The masonry walls should be built in construction lifts not exceeding 600 mm. Through stones (each extending over full thickness of wall) or a pair of overlapping bond stones (each extending over at least $\frac{3}{4}$ th thickness of wall) must be used at every 600 mm along the height and at a maximum spacing of 1.2m along the length.

c) Provide horizontal reinforcing elements

The stone masonry buildings must preferably have lintel, plinth, gable and roof bands of reinforced concrete. It is mandatory to have at least one band either lintel or roof band in stone masonry construction.

d) Control on overall dimensions and heights

The unsupported length of walls between cross-walls should be limited to 5 m; for longer walls, cross supports raised from the ground level called buttresses should be provided at spacing not more than 4 m. The height of each story should not exceed 3 m. In general, stone masonry buildings should not be taller than 2 stories when built in cement mortar and 1 story when built in lime. The wall thickness must be at least one-sixth its height.

2.6 Common structural problems in Nepal

RCC Buildings

a) Construction deficiency

Very few RCC buildings are constructed with earthquake consideration even in the capital city. In columns, longitudinal rebar of 4-6 nos. of 12mm bars, and ties of 6 mm diameter bars usually gaped at regular interval of 0.15 m up to 0.40 m, are in practice. The larger gap of stirrups is noticed to be significantly contributing in the failure of columns. Buildings lack proper layout of the reinforcements in beams, columns, beam-column joints, lintel and sill bands and foundations. Splicing of reinforcing bars in beams and columns are done in haphazard locations.

Compliance with the available building codes for design and detailing is still lacking and often the buildings with approved correct design are being constructed incorrectly due to lack of sound technical supervision. Tie beam joining all columns in the plinth level is avoided in most RC buildings, which however, is slowing changing.

b) No maintenance of building

Buildings are not maintained or repaired during its service life. In places like Sankhu and Bhaktapur, several houses have stood for centuries making them vulnerable to collapse thus posing a threat to the inhabitants. Even such old buildings which have witnessed and survived several earthquakes are never repaired or retrofitted.

c) Nature of soil

The sub-soil characteristics of the site are not studied while constructing buildings in Nepal. The effect of topographic amplification and local site effects have been clearly identified in view of the localized damage during the 2015 Gorkha earthquake. Areas of Gongabu and Sitapaila of Kathmandu have soil that would be classified as weak to soft soil as per NBC. But, geo-technical investigation of the sites was not mandatory for residential buildings, so buildings were constructed haphazardly without considering seismic safety, as a result of which damage intensity was high in those areas with very low bearing capacity of soil.

d) Short column

Often the reinforcement of RCC staircase is embedded in supporting RCC columns causing short column effect; its effect however is not considered in the design phase.

e) Material quality

Quality of fine and coarse aggregates, water cement ratio significantly affect the strength of concrete, however in Nepal water cement ratio is usually exceeded for achieving workability compromising strength of concrete. In most of the damaged houses, corrosion of re-bars is also recurrently visible. Majority of the RC buildings in Nepal are constructed in phase, in this regard the variation in quality of construction materials and technology. This has led in non-homogenous and non-monolithic construction showing wider variation in terms of structural performance.

f) Soft storey

Generally, no consideration is done for soft and weak story effect. Such conditions are not checked and tackled in the design phase itself. The ground floor in almost 90 % RC buildings is used for commercial purpose and provided with shutters, however the upper stories of such buildings are provided with infill brick masonry walls. Similarly, in case of high rise constructions, the ground floor are left open for parking or sometimes basement parking is provided without infill walls.

Such practices have led the soft storey failure, remarkably during the Gorkha earthquake- 2015 in most of the damaged RC buildings.

- g) **Eccentric footings**
Eccentric footing is not tied together to its adjacent interior footing. The practice of tying all isolated footings together using foundation ties is not followed by many. The isolated footing for a corner column whose two faces coincide with the property line of the building needs special attention since it produces unwanted moments which needs to be addressed with sufficient reinforcement in the footing as well as strapping it with other footings, as appropriate.
- h) **Large openings**
Openings are provided without structural consideration. It is often encountered that large openings are placed near the corners which enhance the seismic vulnerability. Continuous lintel bands are avoided due to negligence or lack of awareness.
- i) **Floating columns**
Floating columns are commonly observed in residential buildings to increase the upper storey floor area by constructing columns that float over cantilever beams. These columns don't have any sub-structure, rather they support over beams or slab. This leads to dis-continuous load path during earthquakes and the lateral forces are not effectively transferred to the foundation.
- j) **Inappropriate addition of storeys**
Due to unavailability of spaces for construction, slender structures are frequent in the city area. Particularly in the outskirts of the Kathmandu valley, with the commercialization of the area, owners tend to add stories themselves, with up to seven to eight stories supported by the same column size designed to withstand a two to three storey building.

Masonry Buildings

- a) **Structural integrity**
Almost all URM buildings in Nepal are found without any bands at various levels like; sill, lintel or gable. Due to lack of proper bonding in masonry load bearing wall, out of plane collapse is more commonly observed due to the recent earthquake.
- b) **Age of buildings**
Masonry buildings in Nepal survive at least three generations. Most of the masonry buildings that were damaged during the Gorkha earthquake were of 70-80 years old. Due to deterioration of strength, buildings reach vulnerable stage even before the earthquake. Aside from very old age of masonry buildings, it is to be noted that almost all houses are not repaired or retrofitted at all during the life span of the building and have witnessed several smaller shakes previously. Due to lack of repair and maintenance, most of the old houses were heavily damaged.
- c) **Delamination**
Traditional masonry construction practice consists of very thick walls even upto 3' thick built as two or more leaves with mud binding. Such mud mortar binding is found to be detached from the masonry units many years back and delamination of wythes is commonly observed due to the earthquake.
- d) **Roof and gable failure**
Most masonry buildings in Nepal are constructed with heavy RC slabs forming the floor levels and using roof tiles with thick layer of mud mortar. The roofing materials are not tied or anchored properly with other structural members and found to be severely damaged during the earthquake. Similarly, the gable portion of most of the masonry buildings is found to be constructed with thick brick wall left hanging without any attachment with other structural members, which has led to toppling of such walls triggering more severe damage.
- e) **Pounding**
Most of the urban fabrics within Kathmandu valley consist row housing. In such housing framework, due to variation in

dynamic properties of masonry units, pounding in terms of wall damage or bulging out of the wall is commonly observed within Kathmandu valley.

Demolition of building

About 20 years ago, urban planning and planned land development was not important. But, in the past few decades, residential buildings have been built so haphazardly in the Kathmandu valley that it looks no less than a concrete jungle. However, newer cities like Pokhara are better planned with wider roads, segregated commercial areas and systematic service distribution. It has not been long since the government has separated a large chunk of budget for urban development which is also a demand of time with the mushrooming numbers of construction ongoing.

At present, there is no other way to re-organize the settlement in Kathmandu valley than to demolish the old buildings and re-allocate them as per an urban development master plan for the city. In places like Sankhu and Bhaktapur, several houses have stood for centuries making them vulnerable to collapse thus posing a threat to the inhabitants. Therefore, the government of Nepal needs to make a strong decision to compulsorily demolish buildings which have crossed a certain age.

Recently also, after the Gorkha Earthquake 2015, many buildings which were severely damaged but survived complete downfall, were demolished. For safe demolition of buildings, several things need to be considered.

Considerations for Demolition of Building

- When falling objects are present, sufficient distance from the building must be safe-zoned for the safety of the by-standers.
- It is mandatory that demolition should be done in pairs, one to look after the other's safety while working.
- Demolition should not be done while raining or when aftershocks are likely to hit. The associated hazards like fire, short-circuit must be taken care of.
- Unstable hanging objects must be removed at first. Only after that, demolition must be begun by removing objects from top to the base.

- The building being demolished should be stable, it must be shored temporarily if required.
- For proper debris management, objects that can be re-used and re-cycled must be separated.
- All unusable waste / debris must be adequately wet to prevent dust at all times and the transport trucks must be covered completely.

2.7 Requirements of earthquake resistant building construction

a) Shape

The geometric parameters qualifying the building shape are the vertical and plan regularity, the symmetry and the compactness. Buildings with simple geometry and symmetry in plan and elevation are good from earthquake resistant point of view. Building with reentrant corners like U, L, V, H and + shape in plan suffer more damage during an earthquake. These plan shapes produce variation in stiffness and hence differential motions among different parts of the building resulting in local stress concentration at the reentrant corner. The other problem caused by this is torsion in horizontal plane. The twisting effect causes higher shear load on far distant columns and walls forcing them to fail. The adverse effect of these entrant corners in the plan of buildings can be avoided by sub-dividing the building into small simple rectangular subdivisions providing seismic gaps so that the separated blocks oscillate independently during earthquakes. However, if the horizontal projections are less than $1/4^{\text{th}}$ of the side, subdivision is not necessary.

Vertical irregularities do not only consist of irregular vertical geometry (30% variation of the horizontal dimension at any story), but also of irregularities of the structural system-stiffness discontinuity (soft story), weight irregularity, discontinuity of vertical lateral force resisting elements, strength discontinuity (weak story). The earthquake forces developed at different floor levels in a building should be transferred to the ground through the shortest and the most direct path. Any deviation or discontinuity in this load path results in poor performance of the building. Buildings with discontinuous columns, floating columns, vertical setbacks

cause a sudden leap in earthquake forces at the point of discontinuity and deformation incompatibility. These situations should be avoided. Building should have uniform stiffness along the height.

b) Proportion

In narrow but very long buildings, the ground imparts very different earthquake vibration to various parts of the building causing severe damage to it. So, it is advised to keep the breadth to length ratio of a building within 1:3. The breadth to length ratio for any room or area enclosed by load bearing walls inside the building should preferably not exceed 1:3 as well. However, it does not mean that building with length to width ratio less than 3 but very large in plan is good from earthquake point of view. If the building has large horizontal dimension, the differential arrival of the seismic wave in different parts of the building might pose problems.

In the past, huge emphasis was given on the overall height of the building. But, as the height increases, the natural period of the building also increases shifting it in the range where response amplification is lower. On the contrary, what plays a more crucial role is the shape factor (height to width ratio) of the building. If building is slender, it leads to high compressive and tensile forces on outer columns during a seismic event. This results in rapid strength and stiffness degradation of these columns. It is thus advised that the building height should not be more than 3 times the width of the building.

c) Foundation

Detailed soil investigation must be carried out before any construction. The nature of soil can be different even in adjacent sites. So, the foundation must be designed only after the recommendations from geotechnical engineers regarding the nature of soil deposits, bearing capacity of soil, the position of ground water table, the prospects of liquefaction and so on. Ideally, building must have a strong foundation built on a hard and uniform ground.

d) Ductility

Frames of the buildings should have adequate ductility to undergo large deformation without collapse. Masonry construction is inherently brittle and hence tying all elements up to make it act as a single unit is the best possible defense to earthquake. However, in RCC construction, ductility can be improved by proper detailing strategies following available codes of practice such as IS13920.

e) Redundancy

In simple words, redundancy means holding different systems or elements in reserve, which come into action when distortion increases. Redundancy in the structure will ensure that if an element in the lateral force resisting system fails for any reason, there is another element present that can provide lateral force resistance. It also provides multiple locations for potential yielding, distributing inelastic activity throughout the structure and improving ductility and energy dissipation. Redundancy is improved by providing solid infill walls in moment resisting frame systems, use of braces in the frame, provision of shear walls firmly fixed to the frames and presence of multiple bays in each direction.

f) Minimum torsion

In irregular buildings, during a seismic event, some parts of the building deflect more and some parts less. Due to this difference, the building as a whole tends to rotate leaving the corners and ends at more stress. This rotation of a building is called torsion. The members resisting horizontal forces should be arranged so that the center of rigidity and the center of mass in each floor lie close to each other in both major axes. However, if the twist cannot be avoided, special calculations need to be done to account for additional shear forces in the design of buildings; IS 1893: 2002 has provisions for such calculations.

2.8 Computer Aided Design of building structure

Computer aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis or optimization of a design. CAD software is used to increase the productivity of the

designer, improve the quality of design, and improve communications through documentation and to create a database for manufacturing. Eg, AutoCAD, Chief Architect for drafting, Sketchup, 3D Max, Revit for 3D rendering, STAAD Pro, Etabs, SAP2000 for structural design, SAFE for foundation design, TEKLA for structural detailing, ABAQUS, ANSYS for finite element modelling etc.

However, in using these software, a word of caution is appropriate. These programs should only be used by persons who have a full understanding of what the program does, as well as of the properties of materials, structural behavior, failure modes, structural systems employed, overall deformation patterns, compatibility conditions, load transmission paths to supports and possible weak links, if any. Furthermore, it should be possible to identify the critical and primary load carrying elements and to perform an approximate manual check on the stress resultants and design resistance of such members, in order to avoid gross errors.

2.9 Mandatory Rules of Thumb in building design

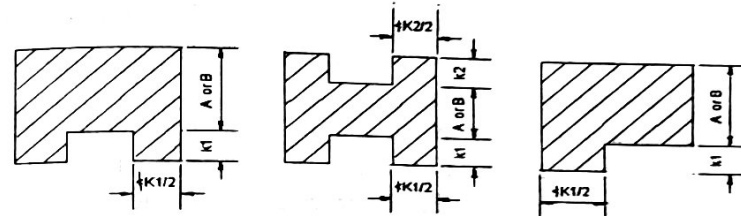
Mandatory rules of thumb addresses the requirements of those buildings which have become very common with owner-builders, who even undertake construction of this type of buildings without employing professional designers. However, the user of MRT are required to comply with certain restrictions with respect to building configuration, layout and overall height and size.

Rules for RCC buildings without masonry infill

Generally, the design of RC buildings is done without considering the effect (except their loads) of masonry infill panel between the frames. NBC 205:2012 presents ready-to-use designs for all structural components, including detailing of structural as well as non-structural members for RC buildings without masonry infill. For a building to be built using this MRT, there are restrictions which are presented below:

- The span of beam shall not exceed 4.5 m.
- There should not be more than 6 bays in each direction.
- Each slab panel must be lesser than 13.5 square meters.

- The length to width as well as height to width ratio must not exceed 3.
- The maximum height of the structure is 11 m or 3 stories, whichever is less, from the level of lateral restraint. However, an additional story of smaller plan area (not exceeding 25% of typical floor area) shall be permitted.
- The length of wings on the structure (k_1 and k_2) shall be restricted such that they are lesser than the 15% of the length of rectangular part in either direction.



$k_1, k_2 < 0.15 A \text{ or } 0.15 B, \text{ whichever is less.}$

- All columns resisting lateral load shall be vertical and shall continue on the same centerline down to the foundation level. The top story may be smaller or have a different geometry subject to the above clause.
- No walls except a parapet wall shall be built on a cantilevered slab. Such walls shall be constructed only if the cantilevered slab is framed with beams.
- The foundation shall be at a uniform level.
- Buildings shall not have a soft story.
- The size of cantilever projection shall not exceed 1 m.

Provided that the building complies with all these, the ready-to-use guidelines on the size and reinforcement detailing provided in this code can be used. Some salient recommendations are:

- Building occupancy: Ordinary building
- Bay dimension: Span upto 4.5m, panel area upto 13.5m
- Nos. of bay: 2 x 2 to 6 x 6
- Nos. of story: Up to 3 plus stair cover
- Story height:
For Terai = 3.35 m
For other regions = 2.75 m

- f) Wall thickness = Up to 115 mm thick brick wall or equivalent for all internal walls and up to 230 mm thick brick wall or equivalent for all external walls
- g) Cantilever floor projection: 1 m (from centerline of beam)
- h) Concrete mix: M20
- i) Reinforcement: Fe415 or Fe500
- j) Mortar: Minimum 1:4 cement-sand mortar for half-brick wall and 1:6 for one-brick wall
- k) Slab thickness: 125 mm
- l) Reinforcement detailing in slab: 8ϕ at 150 mm in all critical sections with appropriate cranking as provided in the detail drawings of the code.
- m) Beam dimension: Width 230 or 250 mm and depth 355 mm including slab for floor beams. For tie beam width and depth 230mm. Tie beam shall be provided at plinth level and footing level. However, tie beam can be avoided in some parts where strap beam has been provided.
- n) Reinforcement detailing in beam: Varies from floor to floor and based on steel grade. Detail drawings provided in the code shall be followed.
- o) Column dimension: 300 mm X 300 mm
- p) Reinforcement detailing in column: Varies from floor to floor and based on steel grade. Detail drawings provided in the code shall be followed.
- q) Foundation dimensions: Footing shall be pad or isolated footing. The dimension varies as per column type (interior, face or corner) and safe bearing capacity of the soil.
- r) Reinforcement detailing in foundation: Bars of 12 mm diameter are provided in both direction, the number of such bars depends upon the column type and safe bearing capacity of soil.
- s) Staircase dimensions: The slab must be 125 mm thick. Tread and rise must be as per building plan and width shall be 1050 mm.
- t) Reinforcement detailing in staircase: The main bars must be 12ϕ at 150 mm c/c and distribution 8ϕ at 200 mm c/c. The drawing provided in the code shall be referred. If landing beam

is provided, it shall be 230 mm X 300 mm with 2- 12ϕ at top and bottom and stirrups 8ϕ at 150 mm c/c throughout.

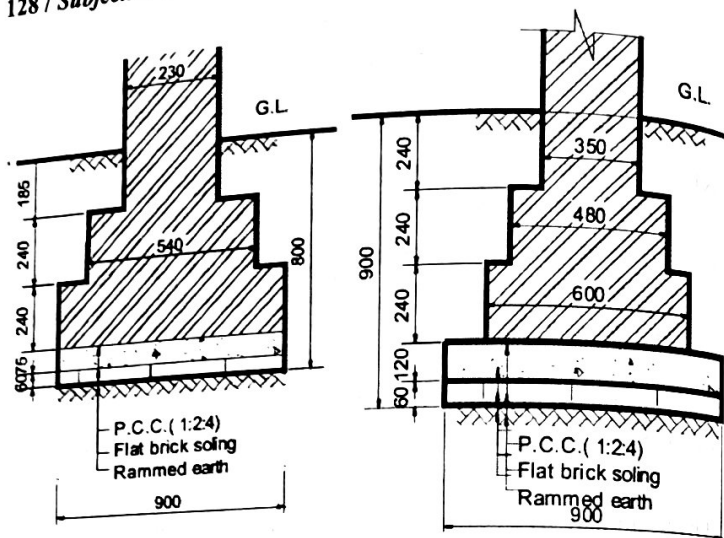
Rules for load bearing buildings

NBC 202 provides mandatory rules of thumb for load bearing masonry buildings meeting the prescribed criteria.

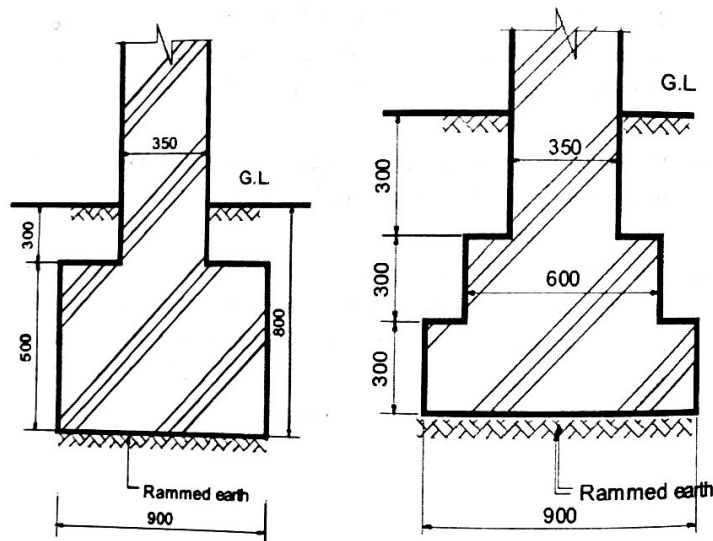
- a) Up to three-storied load-bearing brick (and other rectangular building units) masonry buildings constructed in cement mortars.
- b) Up to two-storied load-bearing stone masonry buildings constructed in cement mortar.
- c) Up to two-storied load-bearing brick masonry buildings constructed in mud mortar.

These limitations does not bar anyone wishing to employ qualified professionals to produce an appropriate design. Structures falling outside these limitations will require specific design. The salient recommendations of the code are:

- a) All load bearing brick masonry in cement mortar shall be at least 230 mm thick for one-story building. In case of load bearing stone masonry in cement mortar and load bearing brick masonry in mud mortar, even for one-story building, the wall thickness shall be 350 mm.
- b) For multi-story building, the ground floor walls shall be 350 mm thick and upper floor walls shall be 230 mm, irrespective of the type of masonry.
- c) The footing for brick masonry on cement mortar for single story building shall be 230mm X 540mm X 900mm stepped over PCC and brick soling for a depth of 800mm and for multi-story building, it shall consist of 350mm X 480mm X 600mm stepped over PCC and brick soling for a depth of 900mm.

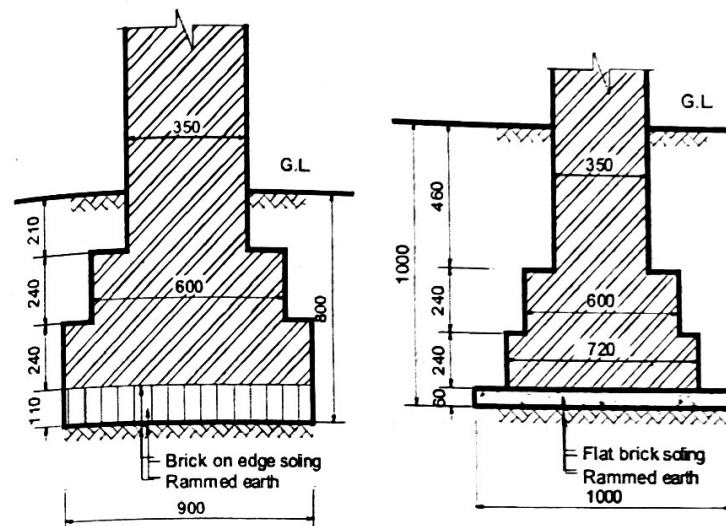


- d) The footing for stone masonry on cement mortar for single story building shall be 350mm X 900mm stepped for a depth of 800mm and for multi-story building, it shall consist of 350mm X 600mm X 900mm stepped for a depth of 900mm.



- e) The footing for brick masonry on mud mortar for single story building shall be 350mm X 600mm X 900mm stepped over brick on edge soling for a depth of 800mm and for multi-story

building, it shall consist of 350mm X 600mm X 720mm stepped over brick soling for a depth of 900mm.



- f) At the plinth level, an RCC band 150 mm thick shall be provided at a height of 300 to 750 mm from the ground level for brick or stone masonry in cement mortar. For brick masonry on mud mortar, a wooden collar band shall be provided at 300 to 450 mm from the ground level. The band is mandatory when the soil is soft or uneven. It also serves as a damp-proof course.
- g) Openings in the wall should be small in size and centrally located. Tops of openings shall be at the same level.
- h) Lintel band must be provided in all openings. The width of RC band must be same as the thickness of the wall and its thickness at least 75 mm with two 10mm diameter longitudinal bars held in position by stirrups 6 mm in diameter spaced 150 mm apart.
- i) Bands similar to lintel band are provided at the eaves level in the form of roof band and in the triangular portion of masonry gable as gable band.
- j) Steel dowel bars are used at corners and T-junctions to integrate the box action of walls. Dowels must be at least 2-8 ϕ longitudinal bars with 6 mm cross ties at 150 mm spacing provided in either direction at the junction which shall extend at least 1.2 m from the central point in the junction.

- k) Vertical steel bars shall be installed at critical sections (i.e., corners of walls, junctions of walls and jambs of doors) right from the foundation concrete. They shall be covered with cement concrete in cavities made around them during the masonry construction. Such concrete mix should be 1:2:4 by volume or richer. The vertical bars at the side of openings should be stopped by embedding it into the lintel band, but the vertical steel at the corners and junctions of walls must be taken into either the floor slabs or roof bands.
- l) Particularly for stone masonry, through stones of a length equal to the full wall thickness should be used in every 600 mm lift at not more than 1.2 m apart horizontally. If the full-length stones are not available, pairs of stones, each about three-quarters of the wall thickness long, shall be used in place of one full-length stone so as to provide an overlap between them.
- m) The roofing structure must be light, well-connected and adequately tied to the walls.

Consideration of infill panels in design

Infilled frames tend to be substantially stronger, but less deformable, than otherwise identical bare frames. In symmetrical buildings with vertically continuous infilled frames, the increased stiffness and strength may protect a building from damage associated with excessive lateral drift or inadequate strength. But, because of its higher stiffness, infill panels may attract significantly greater forces that may lead to premature failure of infill, and possibly of the whole structure. Therefore, it is essential for designers to consider the effects of infills in the design of RC buildings.

National codes specify lower values of response reduction factors for Masonry Infill -RC frame buildings as compared to the buildings without infill, such that masonry infilled frames are required to be designed for 1.15 to 3 times the design forces for the corresponding bare frames. Lower value of response reduction factor is considered for Masonry Infill -RC frames because of lower ductility and a higher degree of uncertainty and seismic vulnerability associated with masonry infill.

A few codes have specified limitations on the elastic and inelastic deformations and inter-story drift ratio of Masonry Infill -RC frames

for damage limitation requirements. Few codes recommend modeling masonry infill using equivalent diagonal struts; however, the required sectional properties for the struts are not specified. Strength and stiffness of masonry infill reduces with the presence of openings. Various ways of reducing the damage in masonry infill due to openings have been discussed in few codes, e.g., framing the openings using RC elements. Full strength and stiffness of masonry infill is not utilized when out-of-plane collapse of infill takes place. A few codes specify limits on slenderness ratio (ratio of length or height to thickness) to prevent out-of-plane failure of masonry infill. Some national codes recommend using light wire mesh and RC tie-bands along the length of walls at various locations to avoid out-of-plane collapse of masonry infill.

In sum, the general practice of bare frame analysis is essentially valid provided precautions to avoid out-of-plane failure of the infill panels are made. In such a case, the non-consideration of infill during design but their presence in actual, keeps the designer in the safe side.

2.10 Non-engineered earthquake resistant building design

Non-engineered buildings are small commercial structures in developing countries which are built by land owners or local artisans without the benefit of engineering or architectural help. These buildings are generally characterized by use of poor materials, poor workmanship and lack of supervision hence making them vulnerable to even minor earthquakes.

The earthquake resistance of such buildings can be improved by,

- a) The walls must be effectively tied together to avoid separation at vertical joints due to ground shaking.
- b) Roof or floor elements must be tied together and be able to exhibit diaphragm action.
- c) Trusses must be anchored to the supporting walls and have an arrangement for transferring their inertial force to the end walls.
- d) Openings must be as small as possible and centrally located in the walls.
- e) Reinforcements must be provided in critical locations in case of masonry construction to improve strength and ductility.

- f) Masons must be trained about correct reinforcement detailing with proper spacing of ties in column and stirrups in beam as well as beam-column joints.
- g) Training for better quality control in construction, better workmanship and adequate skill in bonding with the use of through stones or bonding units must be given to the masons.

Earthquake resistant design models: Gorkha- Nepal Earthquake 2015

The Government of Nepal has published two volumes of design catalogue to fulfil the reconstruction demand in the country after the Gorkha-Nepal Earthquake in 2015. Following the principle of Build Back Better, the Government had decided to provide monetary grant to the earthquake hit beneficiaries who are willing to construct earthquake resistant houses. Particularly in the rural areas, lack of awareness about correct construction practice, still prevails. So, in order to support the reconstruction vision, several design models have been proposed based on calculations, model tests and analytical tests. The design models offer wide variation in coverage area and appearance to suit the requirement of different types of family.

In the first volume, 17 design models using four broad categories of building materials and typology were presented which are as follows:

- a) Stone and mud mortar masonry
- b) Brick and mud mortar masonry
- c) Stone and cement mortar masonry
- d) Brick and cement mortar masonry

There are 17 design drawings with technical specification details, of two room to four room, single storey and two storey buildings of stone or brick in cement or mud mortar using RCC bands and vertical reinforcements or wooden horizontal bands and vertical wooden posts at critical locations of the building.

In the second volume, 17 design models using twelve broad categories of building materials and typology were presented which are as follows:

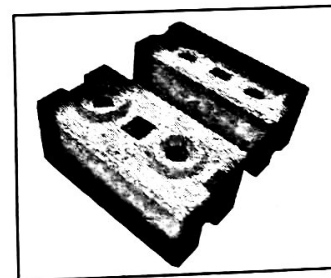
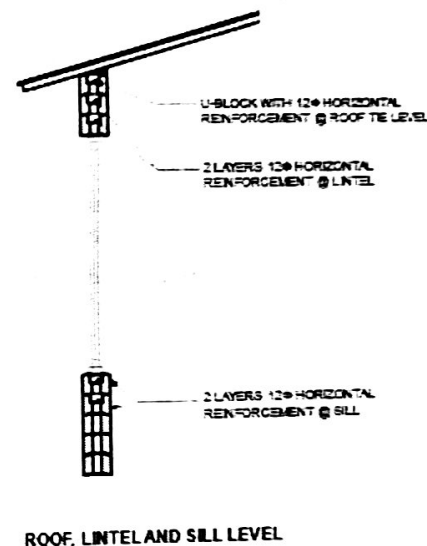
- a) Interlocking brick masonry
- b) Confined hollow concrete block masonry
- c) Hollow concrete block masonry
- d) Compressed stabilized earth block masonry

- e) Random rubble masonry with GI wire containment
- f) Bamboo and stone masonry hybrid structure
- g) Rat trap bond masonry
- h) Earth bag masonry
- i) Light gauge steel structure
- j) Steel structure
- k) Timber Structure
- l) Debris block masonry

a) Interlocking brick masonry

Interlocking brick technology consists of specially designed unburnt bricks 30cm X 15cm X 10cm with tongue and groove feature that allows bricks to interlock each other in masonry and thereby reduces mortar usage. The special design of interlocking bricks allows for vertical reinforcement bars in strategic locations (corners, junctions and sides of openings) of buildings.

Horizontal reinforcement bars are used in sill, lintel and roof bands; in a typical band, 1-12 dia bar is provided in each of 2 layers of special U-shaped interlocking bricks. Both vertical and horizontal reinforcements are grouted with micro concrete (Cement : Sand : Chips 1:2:3). In the plinth band, a minimum of 150mm thick RCC (M20) band with at least 6- 10mm dia bars and 8mm dia stirrups at 150c/c is provided. Construction with interlocking brick is

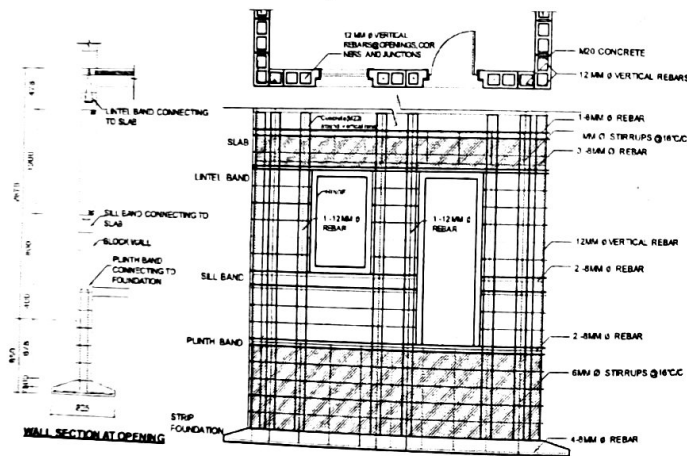


economical, quick and environment friendly. Load bearing walls are formed by interlocking bricks, corrugatedgalvanized iron sheet is used in the roof and precast joist and pan are used for floors.

b) **Confined hollow concrete block masonry**

In this technology, the structural system consists of load bearing hollow concrete block (40cm X 15cm X 20cm) walls confined with 15 cm x 15 cm R.C.C. Columns. To ensure proper connection between the walls and the column, first the wall is constructed up to a certain level leaving space for columns as well as leaving toothing towards the column and then the column is cast monolithically binding the wall through the concrete in the toothing. By this process, the wall is constructed in stages up to the sill level, the lintel level and finally the floor or roof level. A maximum of twostorey can be constructed ensuring seismic safety. The first floor is of at least 100mm thick R.C.C. slab and roofing consists of CGI sheet over wooden rafter and purlins.

c) **Hollow concrete block masonry**



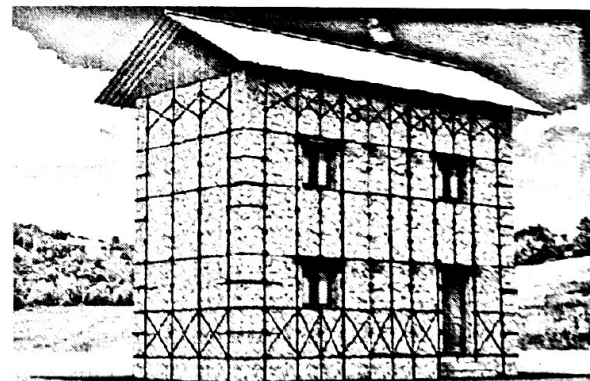
This technology proposes load bearing structure of hollow concrete blocks (40cm x 20cm x 10cm). Hollow concrete blocks are seen as a good alternative to conventional brick masonry as they can be locally manufactured, cheaper and environment friendly. Design features are RCC strip foundation, load bearing hollow concrete walls, precast floor and roof, precast stair slabs, horizontal bands

and vertical seismic reinforcement at critical sections. The design is of modular type, affordable, structurally sound and environment friendly.

d) Compressed Stabilized Earth Block masonry

Compressed Stabilized Earth Block (CSEB) Technology makes use of mud as a predominant building material. Load bearing walls are made of earthen blocks stabilized with flat plug resin chemical. The size of the block used is 30cm X 20cm X 10cm for a single storey building maintaining a minimum wall thickness of 20cm whereas for a two storey building 23cm X 10cm X 5.5cm block is used with a minimum wall thickness of 23cm. Mortar of cement sand in 1:5 or richer is used. Vertical and horizontal reinforcements are provided at strategic locations for seismic resistance. The upper floor is formed by at least 130mm thick RCC slab (M20) over beam 300mm X 230mm. Roof is formed of mud over bamboo truss or CGI sheet over metal truss. The proposed technology is very suitable for rural areas where local materials are used and their quality improved by adding small quantities of non- local materials.

e) Random rubble masonry with GI wire containment



This technology is an improvement on random rubble masonry structure by introduction of GI containment wires. Vertical GI Containment wires are provided on two faces of a masonry wall to prevent flexural failure. The reinforcement on the two faces are connected by ties going through walls to prevent delamination of the walls. The proposed design makes minimal changes in local

construction system. Basic materials like stone and mud for walls, corrugated galvanized iron sheets on timber rafter/purlins for roof and mud flooring on timber deck for intermediate floors are proposed similar to common houses in the hills of Nepal. This technology is suitable in those remote villages where difficulty in transportation of non-local material prevails.

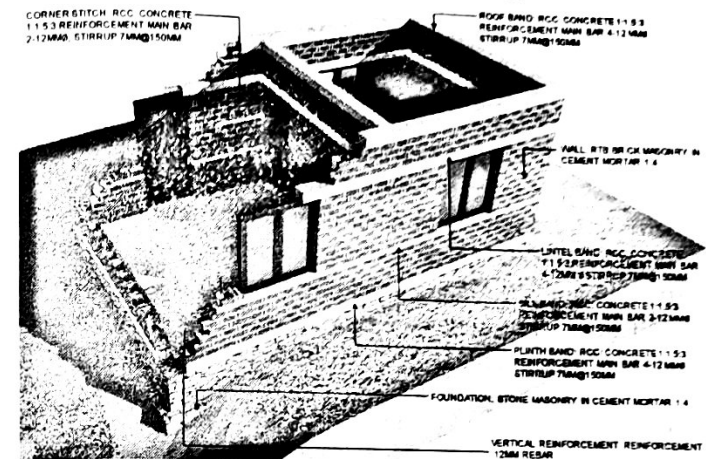
f) Bamboo and stone masonry hybrid structure

The proposed technology uses traditional, yet earthquake resistant construction using materials and skills that are indigenous and locally available. Local bamboo (*Bambusa Nutans*), seasoned and treated, is used in a structural frame with bamboo wattle and daub panels as walls on the upper floor. The frame is surrounded with awall in Stone Masonry with Mud Mortar 45cm thick on the ground floor of the house. For the stone masonry, a strip foundation of width 850mm and depth 750mm is provided whereas for bamboo posts, 150mm x 150mm thick PCC base pad is provided. At strategic locations- plinth, sill and lintel, timber bands of two parallel timber sections of 100 x 50 mm size covering the entire thickness of wall is used along with lateral ties of timber 38 x 50 mm. For upper floors, 50mm thick mud flooring is provided over split bamboos laid on bamboo joists. Light roof truss is used on the top, ensuring proper connection with the walls.

g) Rat trap bond masonry

Rat-Trap Bond is a modular type of masonry construction in which bricks are laid on edge, thereby creating an internal cavity within the wall. The cavity improves the thermal behavior of the wall and significantly reduces the quantity of brick and mortar in the masonry. It is a Green Building technology and an appropriate option against conventional solid brick wall masonry from sustainable point of view. Rat trap bond masonry can be used both for partition wall and load bearing structures. In such construction, strip foundation 800mm wide and 800mm deep is provided using stone masonry in cement mortar and rat trap bond masonry is construction with brick in 1:4 cement sand mortar. As Rat trap bond construction is a modular type of masonry construction, due care must be taken while designing the wall length and height. Horizontal bands, vertical

reinforcements, corner reinforcement and reinforcement in T-junctions are provided as seismic elements. Only a single storey with light roof is permissible using this technology.



h) Earth bag masonry

Earthbag technology is a simple, inexpensive and sustainable method for building structures using ordinary soil (25% - 30% clay & 70% - 75% Sandy soil) found at construction site. A strip foundation of dry stone masonry 600mm wide and 900mm deep is provided after which three polypropylene bags filled with gravel is laid up to the plinth level. The superstructure wall consists of Polypropylene bags filled with locally available soil, laid similarly to masonry (450mm thick) with barbed wire serving as a mortar that provides tensile as well as shear strength. Two strands of barbed wire are tied firmly on top of each course of earth bag. CGI sheet is used for covering the roof along with wooden rafters and purlins. Only one storey construction is permissible using this method.

i) Light gauge steel structure

Cold Form Light gauge steel construction is a structural system consisting of thin steel sections clad with light gauge steel panel, cellular light weight concrete, cement fiber board, gypsum board or calcium silicate board. The steel sections used here are called *cold formed* sections, meaning that the sections are formed, or given

shape at room temperature. This kind of technology requires high level of planning and precision as cold formed sections are fabricated at factory. Similarly skilled manpower are required in site for precise execution of designs.

j) Structural Steel

It is a structural system consisting of mild steel columns and beams to make steel moment resisting framesystem. Both the gravity and lateral load is resisted by moment resisting frame. The floor system is made of profile metal decking system over which thin layer of RCC is laid. The roofing system consists of MS Steel tube truss with CGI Sheet. The infill wall consists of light weight partition wall made of light weight material having density less than 1000Kg/m³.

k) Timber structure

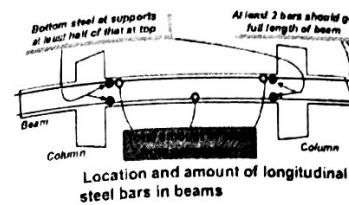
It is a structural system consisting of timber studs (vertical members) and horizontal member load bearing system. The gravity load is resisted by the studs and lateral load is resisted by the timber bracing located at strategic positions. The floor system consists of wooden joist over which wooden planks are laid. The roofing system consists of wooden truss system with CGI sheet. The timber planks are used as light weight partition walls.

l) Debris block masonry

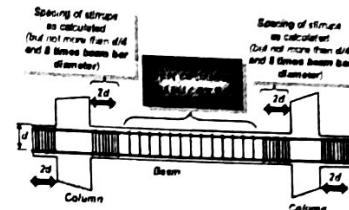
The technology proposes residence construction with block (300mm length x 150mm width x 200mm height) made from stone or brick debris stabilized with cement. The objective of the design is to contribute towards resilient models that helps in debris management as well as improves safety in future earthquakes. Only one storey construction is permissible using this technology. Bands are provided at plinth level, sill level, corner, lintel level and roof level. Roofing is of corrugated Galvanized Iron sheets under wooden rafters.

Seismic detailing of RCC beams and columns

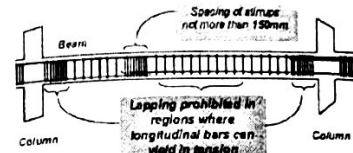
RCC beams:



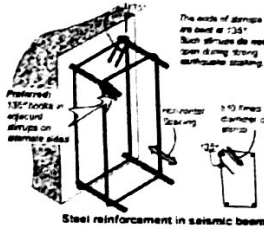
Location and amount of longitudinal steel bars in beams



Location and amount of vertical stirrups

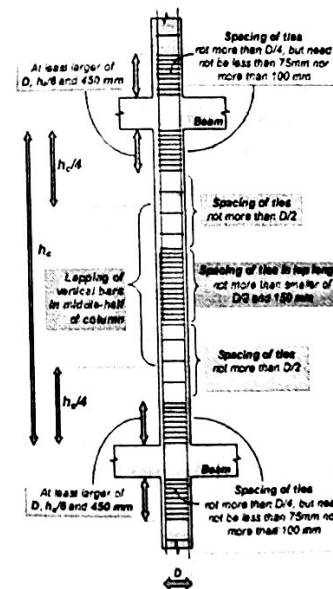


Details of lapping steel reinforcement in seismic beams - as per IS 13920-1993.

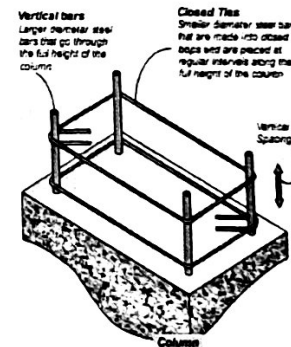


Steel reinforcement in seismic beams

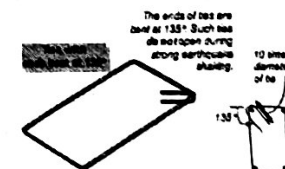
RCC columns:



Placing vertical bars and closed ties



Steel reinforcement in columns

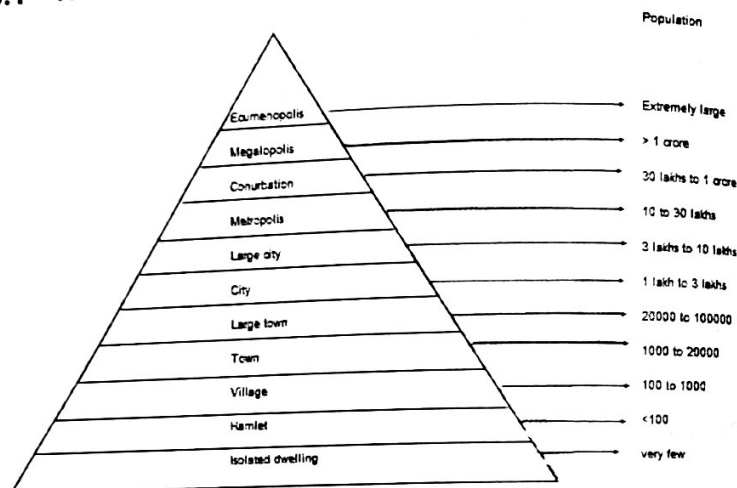


10 times diameter of tie

Section - C

Housing and Urban Planning

3.1 Hierarchy of Urban Settlements



The hierarchy of urban settlement groups a number of settlements according to their size and frequency. As one moves up the hierarchy, the size of settlement increases, while the number of them decreases. As the size increases, the number of services that a settlement provides also increases. So, a metropolis has greater population and better services than a city and the city has greater population and better services than a town. At the same time, there are fewer metropolis than cities and fewer cities than towns.

Central place theory

The spatial implications of regional settlement hierarchies are addressed by central place theory, as developed by German economic geographers, Walter Christaller and August Losch. Central place theory offers an explanation for the relative location of urban places that vary in size and in the number of support activities offered to people living in the surrounding rural area.

The relative spacing of urban places is determined by the 'range', or maximum distance a consumer is willing to travel in order to obtain

a particular goods and service, and the 'threshold', or minimum number of prospective customers a supplier needs in order for business to remain profitable.

Rank size rule

Geographers have described an empirical regularity displayed among settlements within a region that have been rank-ordered according to population size. According to the 'rank-size rule', the population of a particular ranked settlement can be predicted by knowing the population size of the largest settlement in the region. Thus, second ranked settlement should have a population one-half the size of the first-ranked, while the tenth-ranked settlement should have a population one-tenth the size of the first-ranked. A settlement size distribution that follows the rank-size rule is generally interpreted as representing a well-integrated regional economic system, while distributions dominated by an overly large primate city suggest hyper-centralization.

3.2 Types of urban settlements in Nepal

a) Compact settlement

Compact settlements are those in which the amount of built-up area is maximized, with buildings that are either contiguous or nearly so. Compact settlements are characteristic of cultures in hot, dry climates where the close packing of building reduces the external surface area that is exposed to the sun, and puts a good deal of both private and open public space in shade. It also include another reason of security consideration. In this type, street arrangement tends to be arranged such that no more than minimum length of street absolutely required for access to house entrance, is available. It is typical to Newar community that can be observed in old residential settlements in and around Kathmandu valley.

b) Dispersed settlement

It is a type of settlement which has detached houses. This type of settlement may consist of many dwelling groups that are dispersed in a very regular pattern, providing each household with adequate land for dooryard gardens. There is an increasing tendency of detachment of houses which is reasonable from structural point of view.

c) Cluster

Essential nature of the cluster is that it is used to identify group of people or dwellings. A characteristic of many clusters is the similarity of building units to each other. Buildings have often been constructed by collective local labour and share the same form, scale and materials. People who cluster in groups may share a common objective or gather about a feature of common interest.

d) Grid settlement

An organization of streets that lie perpendicular to one another, the grid is among the most controlled of settlement patterns. The square or rectangular plots which the grid defines exercise a discipline upon the form of buildings within its compass. Efficiency in the use of public land, minimizing of street lengths, the provision of sites and services, sewage disposal and electricity supply are among the economic arguments mustered in support of modern grid planning policies.

e) Linear settlement

Linear settlement patterns are generally associated with linear features, either natural or human built. Linear features that may influence settlement patterns include water courses, shorelines, ridge-tops, roads and rails, canals and even political boundaries.

f) Nodal settlement

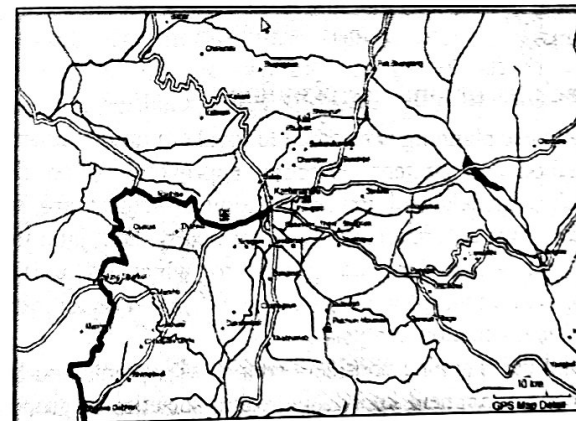
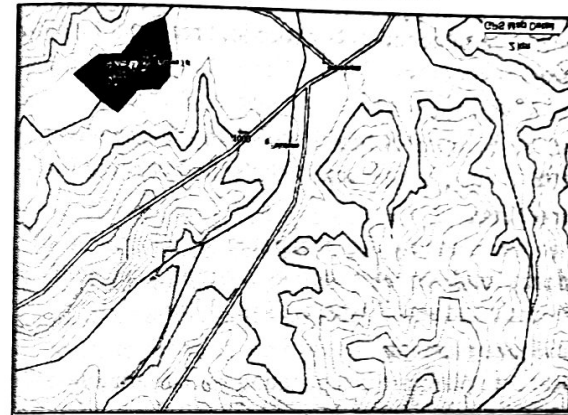
Nodal settlement whether towns or villages, have come to be identified as those on which roads or routes converge forming nodes.

g) Organic settlement

An organic settlement is one that grows over time without being planned in advance. Organic settlements are often contrasted with planned settlements. Such settlements are never static or complete. Streets follow paths that are slightly irregular, building lots and house plans deviated slightly from perfect rectangles, positions of windows and doors may vary from house to house. Settlements that grow in an organic way may be dispersed or compact, linear or centralized, and include large cities and small villages.

3.3 Base map

It is a map that contains visible surface features like roads, rivers, major structures, contour that seldom change. It is used as a template on which further information is placed for the purpose of comparison, spatial correlation or planning urban development. Such maps are created using GIS software.



3.4 Hierarchy of plans

a) National planning

National plans are generally prepared by the individual countries for the overall social and economic development of the country. Plans may be in the form of five year development plan prepared by National Planning Commission (NPC) or annual plans prepared by individual ministries which are then reviewed by the NPC. All development plans including urban, regional and rural

plans are included in the national plan and are implemented as per its specifications.

- b) **Regional planning**
A region is formed by close interaction among cities, towns, villages etc. Planning of such a definite territory is needed for equitable economic development among the regions ensuring integration of common facilities and planned development of the national economy.
- c) **Urban Planning**
It is the planning of urban areas like town, cities, metropolis for better living of people and better economic activities.
- d) **Rural planning**
It is the planning for integrated development of agriculture, industry and services within a rural area with reference to economic and social aspects of rural life.
- e) **Local area planning**
Local area planning is a planning for sustainable development of a specific area within local authority for a specified timescale which has an objective that is consistent with other development plans.

3.5 Principles of land use planning

- a) Land use planning is oriented to local conditions in terms of both method and content. Planning approaches often fail because global models and implementation strategies are applied and taken over automatically and uncritically. But, land use planning is not a standardized procedure which is uniform in its application world-wide. Its content is based on an initial regional or local situation analysis.
- b) Land use planning considers cultural viewpoints and builds up on local environment knowledge. Rural societies or groups can often provide complex indigenous knowledge of the environment. If this is the case, such local knowledge should be part of the basis for planning and implementing a sustainable land use.
- c) Land use planning takes into account traditional strategies for solving problems and conflicts. Traditional rural societies have their own way of approaching problems and settling conflicts concerning land use. In the process of land use planning, such mechanisms have to be recognized, understood and taken into account.

- d) Land use planning assumes a concept which understands rural development to be a "bottom-up" process based on self-help and self-responsibility. The population should actively participate in the process of LUP. The results of planning and the implementation of measures can only be sustainable if plans are made with and by the people, not behind them or even against them. Planning is therefore not just a matter for experts, but should be carried out together with those affected by it. To ensure a feeling of ownership concerning self-help activities, people who are affected have to be involved in the planning process from the early beginning.
- e) Land use planning is a dialog, creating the prerequisites for the successful negotiation and co-operation among stakeholders. The core task of LUP consists of initiating a process of communication and co-operation which allows all participants to formulate their interests and objectives in the dialog. On the basis of sound decision, a sustainable form of land use is proposed whereby the aims and interests of other participating groups are taken into account to the greatest possible extent. An important element of participation oriented LUP is the identification of the various groups of participants and differentiating them in terms of their use of and access to land resources.
- f) Land use planning is a process leading to an improvement in the capacity of the participants to plan and take actions. The participatory methods used in all planning steps of LUP promote the technical and organizational capabilities of all participants, thereby extending their capacity to plan and to act.
- g) Land use planning requires transparency. Transparency in planning and the extent to which stakeholders are informed, strengthen both their willingness and capacity to participate in planning and decision-making.
- h) The differentiation of stakeholders and the gender approach are core principles in land use planning. Men and women often do not have the same access to land and have specific ways of articulating themselves. Different interests are arising from the economic and social character of their roles and scope of duties. Therefore, the role of gender is an important criterion when differentiating stakeholders.

- i) Land use planning is based on interdisciplinary co-operation. The ecological, economic, technical, financial, social and cultural dimensions of land use make it necessary to work with an interdisciplinary approach. Land use planning provides many interfaces with other technical disciplines and planning fields. It uses a broad spectrum of tools.
- j) Land use planning is an iterative process; it is the flexible and open reaction based on new findings and changing conditions. Iteration is both the principle and the method simultaneously. New development and findings are specifically observed and incorporated into the planning process. It may lead to the revision of decision and the repetition of steps already taken.
- k) Land use planning is implementation oriented. It has to consider how the negotiated decisions and the solutions identified are to be implemented. LUP does not end with the land use plan.

3.6 Building byelaws

Building byelaw is a local authority control of building standard promulgated to regulate and control the usage of land, property and areas in cities and towns.

- a) **Planning**
Planning assists in achieving an orderly, efficient and environmentally sustainable development of the municipality by prescribing norms in the issues of right of way, land use zones, degree of building coverage, control of land use for buildings etc.
- b) **Building coverage**
Buildings shall be designed and constructed to comply with the prescribed limitations in size, height and density of building.
- c) **Height of storeys**
The minimum height of storey for a particular territory shall be stated by the local level.
- d) **Height of physical structures**
The minimum height of a physical structure shall be fixed as two times the distance between the center line of the street and the structure to be erected.

- e) Ground coverage ratio and floor area ratio
Ground coverage ratio is the ratio of built up area of a plot at ground level to the total ground area. Floor area ratio is the ratio of total floor area to the total ground area. These values are fixed by the local level based on the location of the site.

- f) **Setback**
Buildings shall be constructed at least some fixed distance away from the plot boundary, which is called setback. Parts of the building shall not cross this line except minor protrusions like sun or rain protection, cantilevers and entrance steps.

3.7 Periodic plans for local authorities

The local Self Governance Act (1999) has made the following provisions for participation and local level planning.

- a) Preparation of periodic and annual plans for the purpose of local bodies
- b) Planning commission and the concerned Ministry of Local Development would provide policy guidelines around the end of November which form the basis of local plan preparation in Nepal.

Steps to follow in the formulation of local plans

- a) Choose the project and program to be included in the annual plans.
- b) Design the structure of plan document and procedures for its adoption.
- c) Adoption of resolution by elected representations of the local bodies that renounces the inter-sectorial and intra-sectorial priorities.
- d) Higher levels have to coordinate and fill in the gaps of local plans.
- e) Integration of local level plans with the district level plans.
- f) Appraisal and approval of plans by an expert political support.

3.8 Planning legislation of Nepal

- a) The first institution for planning was Upatyaka Nirman Samiti, a five member committee formed in 1952 with the mandate of preparing a planned urban development of the main centres of the Kathmandu valley. After a conflict, this committee was

replaced by a small town planning unit established under the Department of Public Works and Building under UN assistance.

- b) In 1969, the first master plan was prepared with technical assistance from UN. It covered a number of aspects of planning and conservation and was expected to complete in 20 to 30 years.

- c) In 1976, another plan called Kathmandu Valley Physical Development Plan was adopted for the development of urban area in Kathmandu. But, the plan had a number of sub-plans such as urban design, residential development, zoning, infrastructure development, building codes for central core areas etc. Unfortunately, this plan largely remained in the file.

- d) With the support of USAID in 1986, the government again prepared a study report as Kathmandu Valley Urban Policy which covered urban land management and land use plan.

- e) In 2013, DUDBC prepared a business plan of urban development and building construction which highlighted the proposed programs in housing, urban development and building sector for the next 20 years. It also illustrated the strategic mega projects for the next 0-5, 5-10 and 10-20 years.

3.9 Environmental issues in urban development

- a) Energy consumption for electricity, transportation, cooking and heating is much higher in urban area than in rural villages
- b) Change in weather pattern due to increase in carbon emission
- c) Loss of biodiversity
- d) Pollution
- e) Traffic congestion

EIA and IEE

Initial Environmental Examination (IEE) is a report on analytical study or evaluation to be prepared to ascertain as to whether, in implementing a proposal, the proposal does have significant adverse impacts on the environment or not, whether such impacts could be avoided or mitigated by any means or not. In building sector, IEE must be done in proposals such as construction of high-rise buildings 10 to 15 storeys, establishment of hotels 50 to 100 beds, establishment of paints, dairy processing, battery, pharmaceutical, plastic industries, construction of cement industries with production

capacity of 30 metric ton per hour based on limestone or 50 metric tons per hour based on clinker, landfill projects with 100 to 1000 tons of waste per year, etc.

Environmental Impact Assessment (EIA) is a report on detailed study and evaluation to be prepared to ascertain as to whether, in implementing a proposal, the proposal does have significant adverse impacts on the environment or not, whether such impacts could be avoided or mitigated by any means or not. In building sector, EIA must be done in proposals such as construction of high-rise buildings more than 15 storeys, establishment of hotels more than 100 beds, development of new airports, establishment of diesel, kerosene, synthetic rubber, plastic industries, construction of cement industries with production capacity of more than 30 metric ton per hour based on limestone or more than 50 metric tons per hour based on clinker, establishment of brick and tile industries with a production capacity of more than 10 million pieces per year, landfill projects with over 1000 tons of waste per year, etc.

3.10 Institutions involved in urban planning and development in Nepal

- a) Central government
 - 1. National Planning Commission
It is responsible for national level policy formulation.
 - 2. Ministry of Local Development
It monitors the role of municipalities under Local Self Governance Act 1999.
 - 3. Ministry of Urban Development
It is responsible for urban infrastructures in the form of urban road construction, sanitation, water supply, construction of public space like parks as well as formulation of housing policy.
 - 4. Department of Urban Development and Building Construction.
It supports municipalities in preparing periodic plans and digital base maps. It also prepares and updates building codes. It monitors building code implementation at several VDCs and also holds awareness programs for safe disaster resilient community. It addresses slum and squatter issues by partnering with NGOs.

5. Town Development committees
It formulates and implements town development plans, enforces building codes and implements land development activities.

6. Nepal Housing Development Finance Company
It provides housing loan facilities at reduced rate.

b) Local government

1. Municipality / Rural Municipality
It implements land development and housing programs. It also enforces construction rules and building codes.

c) NGO / INGOs

1. Lumbini
It improves quality of life for the urban poor through projects of low cost housing and secures shelter for the poor through projects like squatter upgrading projects.

2. Habitat for Humanity International

It is involved in more than 88 countries including Nepal. This organization particularly in 2009 has brought the plan to construct 5000 units of houses in Kavre district as an effort to improve unplanned settlements. It assists other NGOs to build affordable housing using local construction technology.

3. Shelter and Local Technology Development (SLTD) center
is involved in the important works of research, development and dissemination of low cost technology though in a small scale. It is also involved in the production and sale of low cost housing in limited number. The low cost houses constructed in Birauta, Pokhara by Employees Provident Fund under its technical supervision is the largest in terms of number so far. The center has also built some low cost houses in Sitapaila and Satungal in Kathmandu.

d) UN agencies

1. UN-Habitat
It facilitates the government in urban development issues including housing. It also supports in housing disaster affected population in participation with government and NGOs. UN-Habitat Nepal has the responsibility to mobilize 50 million US dollars under Experimental Reimbursable

Seeding Capital (ERSO) established to provide concessional housing loan to poor families for the construction of houses. This agency was also involved in the relief works through the provision of housing to victims of Koshi floods in 2009.

3.11 Types of urban development programs in Nepal Central government

The urban development programs in Nepal Central Government can be summarized in chronological order on the basis of these periodic plans:

- a) During the first five year plan (1956-60), Nepal did not have basic infrastructure services; so attention was paid to supply drinking water, networking of roads and other infrastructures.
- b) In the second five year plan (1961-65), some major roads like Kathmandu-Dakshinkali, Kathmandu-Boudhanath and Kathmandu-Bhaktapur roads were constructed. However, no urban development management was done
- c) In the third five year plan (1966-70), concentration was basically on basic services like drinking water supply and solid waste disposal. The government, however, proposed to run sites and services program to build around 400 houses to be sold to the government servants in Kuleshwar area which was initially planned to be built in Kalimati area. The project was completed much later.
- d) In the fourth five year plan, the government declared four development regions and in the fifth, the Mid-Western Development region was added.
- e) In the sixth plan, the government with the assistance of the famous architect Kantz Tange, prepared a master plan for the development of Lumbini. It was realized that the growing population of urban areas in Nepal would pose a threat to the systematic development of the cities.
- f) In the seventh plan, the government decided to collect detailed information of the urban areas so that the cities could be developed into living places. The plans emphasized on local resource mobilization, institutionalization of urban reforms and preparation and implementation of development plans for urban areas.
- g) The eighth plan focused on the establishment of GIS center, preservation of agricultural land and preparation of national level master plan for transport section. For the first time, the

government provided housing loan through banks and encouraged private housing companies.

- h) In the ninth and tenth plans, many policies and strategies were made and with the assistance of ADB, a comprehensive plan was prepared for the urban area of Kathmandu valley. However, most of the policies and programs were not implemented.

- i) In the eleventh plan, the DPR of outer ring road in Kathmandu valley (47km) was prepared, digital maps of 20 municipalities were prepared, base maps of developing VDCs were prepared and 9900 land plots were created by land pooling. It was also planned to prepare government level policies, norms, guidelines and work procedure to initiate solid waste management, compost plant and sanitary land fill site preparation programs in urban areas of Nepal.

- j) The twelfth plan emphasized on safe and sustainable construction of buildings in accordance with the national building code and using trained masons. For that, programs were implemented to enforce building codes even in developing VDCs of the Kathmandu Valley such as Katunje, Sainbu and Balkot. Similarly, physical infrastructure development programs including road upgradation, waste management, drinking water and urban service provision programs were introduced in those district headquarters which had not been declared as municipality yet. In this period, out of the targeted 30 municipalities, digital maps for 34 municipalities were prepared.

- k) The thirteenth plan (2013/14 to 2015/16) also incorporated physical infrastructure development programs in those district headquarters which had not been declared as municipality. Also during this period, under Biratnagar Ring Road Project, 42km road upgradation work, under UGDP project, infrastructural development program in 6 municipalities - Mechinagar, Itahari, Dhankuta, Lekhnath, Baglung, Tansen and under Secondary Towns Integrated Urban Environmental Improvement Project, integrated infrastructure development project including Road, Sanitation, Auto Village related works in 3 municipalities- Biratnagar, Birgunj, Butwal were initiated.
- l) The fourteenth plan (2016/17 to 2018/19) targets to begin construction / development of 3 administrative plazas, 6 conference halls, 21 integrated government office buildings, 35

bus parks, 7 urban service centers, 21 urban parks, 13 smart cities, 100 hectares of land development and integrated urban development of 18 towns.

3.12 Conservation of heritage sites

At present the sole authority on Heritage Conservation lies with the Department of Archeology, the central government agency. Municipalities or VDCs have little authority regarding preservation and proper utilization of the Ancient Heritage existing inside their area.

Steps for conservation of heritage

- a) Local govt. must be given final authority for conserving heritage.
- b) Action plans for mobilizing local resources have to be implemented through local govt. for conservation activities.
- c) The local community and NGOs must be encourage to run effective programs to educate local people about conservation.
- d) Central government should provide subsidy on traditional construction materials for private house owners inside monument zone.
- e) Illegal re-construction of old private buildings should be controlled.
- f) Provision of national level award to Heritage Conservation activities must be initiated.
- g) Facilitation of networking among agencies involved in Heritage Conservation activities within and outside the country for sharing ideas and experiences in this field.

3.13 Settlement planning for disaster mitigation

Nepal is a disaster prone country susceptible to landslides, flood and earthquake. In the housing sector, many buildings have weak foundation, unsound walls and no provision for fire escape, flooding etc. despite the fact that National building code does incorporate these issues.

The three major players in promoting disaster resilient buildings are DUDBC, municipalities and NGOs. DUDBC is giving training to masons, engineers and overseers on an annual basis in every district of Nepal. It has also published several pamphlets, booklets and posters with information about NBC and earthquake vulnerability reduction. In partnership with NSET and UNDP, the

department is organizing various symposiums and workshops to stimulate compliance with NBC and prepare communities for disastrous incidents.

3.14 Municipalities of Nepal and their roles in urban development

The municipalities became responsible for housing development with the promulgation of Local Self Governance Act 1999. The specific objectives of municipalities are:

- a) Promoting the economic, social and cultural development of Nepali citizens.
- b) Carrying out city level developmental programs including the provision of infrastructure such as road, drainage and water supply.
- c) Coordinating and supervising developmental activities in urban areas under their jurisdiction.

Municipalities have the power over building activities in the form of issuance of building permits. They have the authority to adopt town development plans and implement land development and housing programs. In recent years, seven municipalities (Banepa, Dhulikhel, Panauti, Hetauda, Bharatpur, Ratanagar, and Kamalamai) under the Urban and Environmental Improvement Project conducted land pooling projects in 70 hectares land with loan assistance from ADB. Local governments in several cities have started to work with NGOs and slum dwellers' organizations to address their development issues. Assisted by Lumanti, the municipalities of Bharatpur, Dharan and Birgunj had prepared maps of slums and squatter settlements including characterization of living conditions.

3.15 TDC and role in urban development

The town development committee play the following roles,

- a) Formulate and implement town development plans.
- b) Engage in land development activities like land pooling, guided land development and sites and services programs.
- c) Enforce building codes and construction rules and impose fines or order demolition against illegal construction.

After the promulgation of Local Self Governance Act 1999, its responsibilities have been largely taken over by municipalities.

The role of the committee has been reduced to assistance in DUDBC oriented plans and projects.

3.16 Different types of housing

- a) Permanent housing

It refers to the housing used for residential purpose in which the occupants have sole ownership of the property. Most private residential buildings fall in this category.

- b) Group housing

When two or more groups of occupants have shared ownership over the property and the associated facilities and services, such a housing is called group housing. Apartments fall in this category.

- c) Mixed housing

It is a housing which provides basic facilities including shelter but is also used for non-residential purposes.

- d) Rented housing

Rented housings are residential buildings in which the occupants don't own the living space but rather agree to pay a pre-determined rent on the basis of formal contract or mutual understanding between the owner and the tenant.

- e) Temporary shelter units

These housings provide quick relief to families who have been forced to stay homeless due to natural disaster or warfare. Housing is of low-cost with minimal facilities which are set up until formal relocation of the affected families is arranged.

3.17 Principles of housing

- a) Buildings should serve purposes specified by the client.
- b) It should be constructible by known techniques and with available labor and equipment in an acceptable time.
- c) It should withstand normal usage for a time specified by client.
- d) Both inside and outside, the building should be visually pleasing.
- e) Building should provide for safe evacuation in emergencies.
- f) It should be constructed to minimize adverse impact on the environment.
- g) Operation of the building should consume minimum energy while permitting the building to serve its purposes.

- h) The sum of costs of construction, operation, maintenance and repair must be within the affordable limits specified by the owner.

3.18 Different models of land development

a) Land pooling

Land pooling is a technique for managing the land of urban fringe whereby an agency consolidates a selected group of land parcels and then designs services and sub-divides them into a layout of streets, open spaces and serviced building plots. A certain percentage of land is taken for the streets and public open spaces (approx. 30%) and the remaining building plots are transferred back to the original owner. It is based on self-financing principle, in which the entire cost of the project is recovered by the sale of some of the serviced plots. It is legally backed up by Town Development Act 1998.

b) Sites and services program

It is a program in which the underdeveloped raw lands are acquired and the physical infrastructures like road, piped water, sewer lines, electricity, open and commercial space are provided to form serviced land. A number of such schemes have been launched by TDCs like Kuleshwar in Kathmandu and Bhaisepati in Lalitpur.

c) Guided land development program

It was needed due to rapid private housing construction in agricultural land creating problems of roads. It involved voluntary contribution by land owners to construct new roads, expand existing roads and establish missing linkage in road networks. The program used town plans prepared by DUDBC as a starting point.

3.19 Squatters and slums

Slums are legal but substandard settlements. Slum communities are inhibited by socially disadvantaged who are poor, have low income and inadequate living conditions.

Squatters are illegal settlements especially on hazardous lands such as beside railway track and along rivers and canals. Squatter communities start with a few families finding a vacant piece of land and establishing home there. If they are not evicted, more families join and the settlement expands. In the early stages, settlements have poor quality of houses with no services but later

people find ways to access basic services. Often sanitation and paved access are completely ignored.

3.20 Private housing development

The high influx of population to cities particularly in Kathmandu valley, Pokhara and Birgunj in recent years, inflow of remittance fund from workers outside the country, availability of housing loans and improvement in construction technology have encouraged private developers. The promulgation of Apartment Ownership Act 1997 has provided legal framework for the development, sales and management of multi-story buildings and paved roads for entry into such buildings.

The first private developer was Tashi Rijal Industries which started business in 1980s but their apartments were difficult to sell until the 1997 Act. In 2000, Ansal Chaudhary Company launched an apartment based housing project Kathmandu Residency in Lalitpur which had 180 apartments. Since then around 150 private companies have registered with Nepal land and Housing Developers' Association out of which most are in Kathmandu, Pokhara and Bharatpur. Among them only 40 to 50 focus on residential sector, the majority caters for public, utility and office sector.

3.21 Rural housing, housing development programs in Nepal

Housing programs in Nepal

a) People Housing Program

It is the responsibility of the state to guarantee the provision of social and economic security including land for those groups who are socially and economically backward. In order to fulfil this objective, the government of Nepal has implemented JanataAwaskaryakram from the fiscal year 2066/67 in three districts Siraha, Saptari and Kapilvastu to provide housing by constructing low cost modern housing for Dalit and deprived Muslim families. Altogether a total of 2274 houses in the settlements of 17 villages of Siraha, Saptari and Kapilvastu districts are in the process of completion which was started with the budget of Rs 30 crores being allocated to DUDBC under its annual program of FY 2066/67. Taking into consideration the popularity and usefulness of the program, the budget of FY 2067/68 also continued this program by including the settlements of Chepang, Raute and Kusunda

under this program and policy has been established to include other ethnic groups and communities in future. Presently, the program has been extended to 23 districts. Up to the end of fiscal year 2070/71, altogether more than 3600 housing units have been constructed. A typical house is 324 sqft comprising 2 rooms of size 10 ft X 8 ft and 5 ft width of verandah along with separate kitchen and toilet. The wall and roof of house are made up of bricks and CGI sheet respectively. The cost estimate of a single house is below NRs. 2 lakhs which is largely borne by the government as a grant.

b) Land development program

Although expected results were not achieved from the Kuleshwor and Golfutar sites and services project, these projects made about 1200 developed plots available. Compared to sites and services program, land pooling program is becoming more popular at present. Land pooling program which is so far mostly confined within Kathmandu valley, has been gradually extending outside the valley. Until now, 11000 developed plots have been produced from the completed land pooling projects in the Kathmandu valley which were implemented in 4500 ropanis of land. From the ongoing land pooling projects under implementation in 8000 ropanis of land will produce about 15000 developed plots. Similarly, the Kirtipur second phase project and Nakhudole land pooling project planned for implementation in 1200 ropanis of land in near future is expected to produce about 3000 developed plots. Generally, though it is claimed that the developed plots are targeted for medium and low income groups, but in reality only high medium and upper income groups seem to have the affordability to purchase these developed plots.

c) Low-cost rental housing project

Lumanti, a non-government organization, started a rental housing project for low-income families. The project influenced the govt. to come up with a policy to promote rental housing to offer affordable homes to the poor. Lumanti built a four-story building on 9.5 Annas of land in Dhobighat, Lalipur. Each of the 24 units had an area of 180 sq. ft. and included a kitchen corner, toilet and balcony. The project, supported by UK based NGO Homeless International

incorporated green features like bio-climatic design, rain water harvesting, ground water recharge and solar power LED lights.

d) Rehabilitation of bonded labors (Kamaiyas)

The government on Shrawan 2, 2057 BS, has banned or prohibited to use any individual as a bonded labor directly and indirectly for works by declaring free the bonded labors of Dang, Bardia, Kailali and Kanchanpur who had been forced to work and stay in other's houses for a long period of time after clearing the loan being borrowed by bonded labors. As per Bonded Labor Rehabilitation Implementation Committee of Bonded Labor Rehabilitation Problems Solving Commission under Land Reform and Management Ministry, there are 27,570 bonded families. Of them, till now 23,857 families have been rehabilitated and still 3713 families are remaining to be rehabilitated. Government has been rehabilitating bonded labor families by purchasing land equivalent to Rs. 150,000 and also providing cost for construction of house besides implementing different skill oriented and income generating programs.

e) Bamboo Eco-housing project

It was a social housing project that was supported financially by Global Environmental Facility- Small Grant Program and International network of bamboo and rattan. The project was implemented in Kanchanpur to target the Kamaiyas, a recently liberated bonded labour. The project had four components- bamboo housing, bamboo based enterprises, energy production and resource based rehabilitation.

f) Green Homes: Promoting sustainable Housing in Nepal

Nepalese cities are facing challenges in water scarcity, waste management and environment pollution. To enhance sustainability and adapting climate change impacts, it is necessary to include eco-friendly practices and curb energy consumption in housing sector. UN-Habitat and partners launched Green Homes (2013-15), a project funded by the European Union under SWITCH Asia Call for sustainable consumption and Production. This three year project will be implemented primarily in Lalipur, Pokhara and Dharan. It incorporates five major areas- green building, passive solar design, energy efficiency, water conservation and sustainable management of waste and waste water at household level.

3.22 Prospects of apartments and group housing in Nepal

Most houses in Nepal are owner built. The owner buys land through personal contacts, approaches trained engineers and architects for site plan required to apply for building permit, hires manpower for construction, purchases materials in the market and starts construction using his / her own savings. But, in the past 15 years, with high influx of population in cities, inflow of remittance fund, availability of housing loans and improvement in construction technologies, the formal housing market is emerging. The promulgation of Apartment ownership Act 1997 provided legal framework for the development, sales and management of multi-story buildings and paved roads for private sector developers to enter into the housing sector. At present, more than 150 private companies have registered with Nepal Land and Housing Developers' Association, most of which are working in Kathmandu, Pokhara and Bharatpur.

As of yet, the supply of housing estates and modern complexes is mainly geared towards the upper middle class including non-resident Nepalese living abroad. In fact, many of the developers specifically target them and organize housing exhibitions in America and Australia as part of marketing programs to attract their clients. Though there is huge demand of housing from medium and low income groups, the houses produced by these companies are very far from their economic reach. In selected commercial locations like Thamel, Newroad and Durbarnagar, land prices have surged up so high that even the upper medium income group customers have been left out.

There has been millions of investment from banks and financial institutions in this sector. However, in December 2009, Nepal Rastya bank tightened their lending to housing sector to control unproductive investments. According to their monetary policy, the ceiling or restriction has been placed whereby banks and financial institutions are not allowed to invest more than 25% of the total investment in housing and real estate. As a result, the apartment and group housing sector has witnessed a decline in transaction to some extent. But, overall, the prospects of this sector is good in Nepal.



Section - D

Architecture

4.1 History of architecture

Architecture is the art of organizing space. It is the science of planning elegant, beautiful and comfortable buildings for human purpose. The history of architecture is a record of man's effort to build beautifully. The erection of structures devoid of beauty, just for utilitarian purpose, is merely a building, a trade and not an art. Only when the idea of beauty is added, the structure takes its place among works of architecture.

a) Architecture of prehistoric times

Before recorded history, humans constructed earthen mounds, stone circles, and megaliths which have vanished with time.

b) Ancient Egypt (3050 BC to 900 BC)

In ancient Egypt, powerful rulers constructed monumental pyramids, temples and shrines. Enormous structures such as the Pyramid of Giza were feats of engineering capable of reaching great heights.

c) Classical (850 BC to 476 AD)

Buildings were constructed as per precise rules called the Classical Orders which defined column styles and entablature designs.

d) Byzantine (527 AD to 565 AD)

After the capital of Roman Empire was moved to Byzantium in 330 AD, Roman Architecture evolved into a graceful, classically inspired style that used bricks instead of stones, domed roof, elaborate mosaics and classical form.

e) Romanesque (800 to 1200 AD)

As Rome spread across Europe Romanesque architecture with rounded arches, thick walls and heavy piers emerged.

f) Gothic Architecture (1100 to 1450 AD)

Pointed arches, ribbed vaulting and flying buttresses led to more gracious architecture.

- g) Renaissance Architecture (1400 to 1600 AD)
It is marked by a return to the classical orders of ancient Greece and Rome.
- h) Baroque Architecture (1600 to 1830 AD)
The Baroque style is reflected in opulent and dramatic churches with irregular shape and extravagant ornamentation.
- i) Rococo Architecture (1650 to 1790 AD)
Builders constructed graceful white buildings with sweeping curves decorated with vines, scrolls and shell-shapes.
- j) Modernist style (1900 to present)
The 20th and 21st centuries have seen dramatic changes. Modern day trends include Art Moderne and Deconstructivism, Formalism, Modernism and Structuralism.
- k) Post modernism in Architecture (1972 to present)
A reaction against modernist approaches gave rise to new buildings which re-invented historical details and familiar motifs that date back to classical and ancient times.

Vernacular architecture and its advantages

Vernacular architecture uses locally available resources and tradition in order to address local circumstances. It tends to evolve over time to reflect the environmental, cultural and historical context. Primarily, climate and culture influence vernacular architecture.

Such architecture has been developed to meet specific needs within each cultural milieu thus accommodates values, economies and ways of living of the culture that produces them. The way of life of building occupants, and the way they use their shelters, is of great influence on building forms. The size of family units, how food is prepared and eaten, how people interact and many other cultural considerations will affect the layout and size of dwellings. Occupants even decorate buildings in accordance with local customs and beliefs.

The other major influencer is the macro climate of the area in which the building is constructed. Buildings in cold climate invariably have high thermal mass or significant amounts of insulation. They are usually sealed in order to prevent heat loss and

openings tend to be small or non-existent. Buildings in warm climates, on the contrary, tend to be constructed of lighter materials and to allow significant cross-ventilation through openings in the building. Buildings take different forms depending on precipitation levels in the regions, leading to dwellings on stilts in many regions with frequent flooding. Flat roofs are rare in areas with high levels of precipitation. Similarly, areas with high winds will lead to specialized orientation of the building in order to present minimal area to the direction of prevailing winds.

It has the following advantages:

- a) Merging of forms and skylines:
The forms and skylines of building blend or merge perfectly with their surrounding physical / natural environment that they seem to enhance the beauty of the place.
- b) Uniformity / Order
The houses are laid out following natural topography and in harmony to neighboring houses, visually and spatially. So, the uniformity of their layout and skylines give a pleasing impression.
- c) Natural texture and color
Vernacular architecture uses local materials in their natural texture and color, which maintains perfect harmony between the building and its surrounding natural environment.
- d) Judicious spatial planning
The spatial layout, interior or exterior, addresses well to local climate and socio-cultural needs through orientation of house, its openings and layout of open / semi open spaces.
- e) Individual house and its identity
Each house seems to present its own identity within the settlement cluster.

4.2 Contemporary world Architecture

The modern world architecture can be described by simplified and unornamented building styles of late 19th and 20th century. In this style, the form of the building was determined by functional requirements and materials to be used; all unnecessary details were banished. Materials like glass, steel, iron, concrete were

widely used in construction. Use of sunshades, emphasis on open continuous interior space, use of flat roofs and rectangular forms were some salient features of this style.

Some prominent modern architects include Louis Sullivan and Frank Lloyd Wright in the US, Otto Wagner in Vienna, Victor Horta in Brussels, and LeCorbusier in Gropius Germany. Notable buildings in the modern style are the Home Insurance Building in Chicago and Seagram Building in New York.

The principle problem with modern architecture was its uncompromising focus on functionality and rectilinear form. There was no inclination to give designs more humanizing touches and no concession to local styles. Critics of this style argued that aesthetics is as important as functionality and began to move towards more organic designs of post-modernism.

4.3 Contemporary Nepalese Architecture

Modern architecture started in 1950 with a few aspiring foreign architects who practiced in Nepal. Robert Weise was one of them who designed Hotel Annapurna at Durbar Marg in 1965. Similarly, international architects like Louis Kahn designed Family Planning Center (now Ministry of Health) in 1970. During the 70s and 80s, Tribhuvan International Airport and Narayanhiti Palace were constructed. With the induction of tourism, Nepal witnessed the blending of heritage with modern expression of hotels like Taragaon Regency, Fulbari Resort and Dwarika Hotel in the earlier parts of 2000 AD.

Some new ways of expression in contemporary form were exemplified by ICIMOD building and Mountaineering Museum in Pokhara. As new architectural thoughts emerged, young architects inducted new forms in Laxmi Bank Kathmandu and Krishna Tower. So, the architectural history may have taken different forms of expression as new materials emerged, but the shape and scale of buildings are still guided by ancient heritage to a large extent.

4.4 Traditional Architecture of Nepal

The earliest epigraphic records of Nepal is the Lumbini Pillar inscriptions by Emperor Ashoka dating back to 257 BC. The real

recorded history of Nepalese architecture starts in Kirant Dynasty (500 to 900 AD). The Changu Narayan temple in the eastern fringes of Kathmandu is cited as one of the heritage sites by UNESCO. Its architecture illustrates artistic achievements and skills. Another ancient religious complex of Lichhavi Period is Swayambhunath. It is a stupa consisting of a dome at the base, above which is a cubical structure painted with eyes of Buddha looking in all four directions.

After the Kirants, came the Thakuri Dynasty (900 to 1200 AD). The epitome of this Dynasty in terms of architectural expression is Kasthamandap temple though it was later renovated by Laxmi Narsingh Malla in the 16th century. The Kasthamandap is believed to be built using the trunk of a single tree.

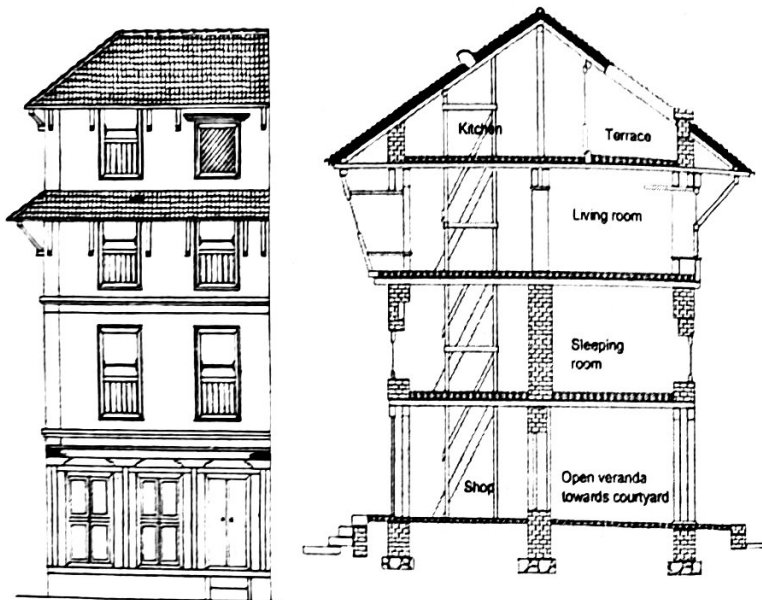
The glorious part of architectural expression came in Malla period (1200 to 1800 AD) when Kathmandu, Patan and Bhaktapur Durbar Square were built. Temples were mainly Pagoda style as in Taleju Mandir of Bhaktapur but Krishna Mandir in Patan adopted Sikhar style. The familiar and widely used Pagoda form starts with a square base often sitting on a pedestal and the form is diminished as it gets higher culminating in a pinnacle called Gajur. Other craftsmanship in the form of wood and metal that are clearly seen in the overhang of Pagodas, in the detailing of the facades and opening levels of temples.

Following the Malla dynasty, the Shah Dynasty (1800 to 1950 AD) had influences of Colonial Architecture from the British Empire at India, which can be seen in buildings like Seto Durbar, Singh Durbar and to some extent in Dharahara.

4.5 Architecture of Kathmandu Valley

The initial buildings in Kathmandu valley developed from what is called "Pakwocha", simple temporary huts built up of mud, sun dried brick and wood structures and used for guarding crops, gathering of farmers at the field for eating and even store house for fire wood. The architecture of the Pakwocha is believed to be the beginning from which the traditional Newari dwelling later transformed. The traditional residential buildings in Kathmandu Valley are three to four storied high, 1.8 to 2.4m tall storey connected by narrow and steep wooden staircase. The plan in

usually a simple rectangle with depth about 6m and range varying from 3m to 10m. The buildings are load bearing, supported by 2 to 3 brick thick masonry walls in mud mortar while stone or brick are used interchangeably in the foundation. The floor is formed by wooden beams and planks. Timber is also used in windows, doors, struts to support projections as well for decorative carvings. The roof is a good architectural feature of the whole building, which is usually in slope with tile roofing called "Jhingati". It is constructed with wooden beam over which wooden boards are placed and then a thick layer of mud topping is applied to support the Jhingati tiles on the top.



The buildings, more importantly those which overlook the main access roads, have symmetrical facade and finely detailed and carved windows and doors.

Elements of Typical Newar Dwelling in Kathmandu Valley

i) Jag (Foundation)

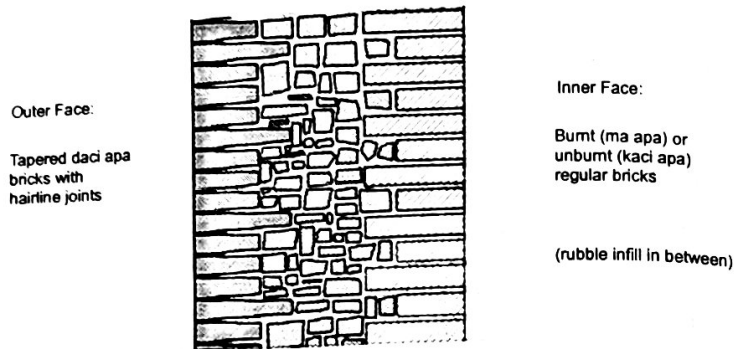
Generally, the foundation is not deeper than 1m and not wider than 70 cm, sometimes stepped. At the lower most level, thick lohan aanga (stone wall / large pebbles) is provided and then burnt brick

wall is constructed on it using mud mortar. There is no practice of damp proof course in the foundation, but for prevention from damp, a layer of stone is provided.

ii) Anga (Wall)

There are three types of wall in a Newar house- the center wall (dathu anga), the external wall (pithu anga) and the partition wall (bhikha anga). The external walls and center walls differ only by their position in the house, both of these walls have structural function and hence are generally around 45 to 75 cm thick. The outer and inner face of the walls are mostly separate. The outer face is made of a wythe of burnt brick, locally called *ma apa*, and the inner face is made of a wythe of burnt or unburnt brick (*kachi apa*). In between the two leaves, a core of brick or rubble infill is done. Commonly, all bricks of the outer face are laid as runners, so there is no or only little bonding between the different leaves. At junctions and corners, cross walls are simply butt jointed with no interlocking at all. The mortar used mud traditionally, although lime mortar gained popularity for a short span of time before the 1934 earthquake, after which its use was extremely limited.

The non-load bearing type of wall, *bhikha anga* is a thin wall constructed to separate and generate interior space. It consists of a single leaf only. Instead of brick partitions, *Sipu Bhikha* (Wooden partition) is also common in typical Newar dwellings of Kathmandu valley. It consists of a main frame (*sipu maa thancha*) in which a pile of wooden planks (*sipu*) is arranged to form a thin partition. Instead of planks, the use of plywood or veneers is also observed in many houses.



iii) Ba (Floor)

Floor consists of Nila (beam), dhalins (joist), wooden planks and the flooring material. Nila is a horizontal member that rests upon the post (tham) and carries the whole load of the dwelling. Dhalin is the horizontal structural member which holds the weight of the floor (ba:). Dhalins are placed close to each other at a spacing of 1' to 1'-6" apart in typical Newar dwellings. These member rest upon beam or wall. Dhalins are held at position with locking arrangements using peg (chuku). Over the dhalins, a number of small wooden planks are compactly placed with no voids left in between the planks. On top of that, sand (cha) is laid uniformly and the final layer of flooring is generally formed by an inch thick square shaped brick, locally called chika apa.

iv) Lukha (Door) and Jhya (Window)

Most of the traditional Newar houses have two frames in the openings, the outer called pichuthan and the inner called duchuthan. These two thans (post) are connected at four places by using interlocking members called tangs which in turn are secured at their place with the help of pegs (chuku).

v) Swona (Staircase)

Since the height of the storey in a Newar dwelling seldom exceeds 2.1m, steep and narrow flight of seven to nine steps typifies a Swona. It is positioned parallel to the dhalins. A dhalin is shortened and placed perpendicular to the other main dhalins, which is the resting point of the staircase. This is called half joist (betwa dhalin)

vi) Roof

Newar dwellings have wide projecting roofs that protrude more than one meter from the facade, even up to two meters in large buildings. All roofs are pitched purlin roofs with a slope of about 30 degrees. The whole weight of the roof is supported by thayma (ridge beam). Ridge beams are typically supported by kingposts. The inclined members or rafters, locally called musin, rest on the ridge beam. A layer of horizontal wooden planks is placed on top of the rafters. A thick layer of mud 5 to 20 cm thick is put over it and finally jhingati tiles are pressed on to the mud. These features of the roof are clear response to the climate condition in Kathmandu valley. The thick mud is used to ensure reasonable cooling and the massive projections protect the walls from relentless monsoon rains.

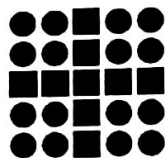
A special feature in the roof is the magnificently carved wooden bracket (tunalas) set at an angle of approximately 45 degrees and spaced at about 2m center to center resting either on a brick cornice or a wooden ledge of a slightly projecting beam which is used to support the overhanging at the eaves.

Architecture of Cultural Heritage in Kathmandu Valley

The architectural heritage of Kathmandu has evolved over centuries of craftsmanship influenced by Hindu and Buddhist religious practices. The architectural treasure of the Kathmandu Valley has been categorized under the well-known seven groups of heritage monuments and buildings which were declared as "World Heritage Site" in 2006 under UNESCO. The seven monuments include Durbar Square of Hanuman Dhoka, Hindu temples of Pashupatinath and Changuarayan, the Buddha stupas of Swayambhunath and Bouddhanath and the Durbar Squares of Patan and Bhaktapur. Kathmandu has been described as "Land of Gods" and as "Land of Largest Congregations of magnificent historical monuments and shrines ever built". The city core has most of the remarkable cultural wealth that evolved during the reign of Malla Kings between the 15th and the 18th centuries. The city is filled with sculptures, pagodas, stupas and palace buildings of exceptional beauty. There are 106 monastic courtyards known for their art and piety.

4.6 Principles of architectural design

a) Unity



It is the blend of all elements that creates a feeling of harmony between all parts of design. It gives a sense of completeness. There must be a balance between unity and variety to avoid chaotic or lifeless design.

b) Balance



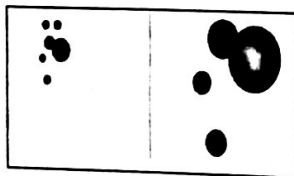
It is a state of equalized tension and equilibrium so that no space is away from the whole.

c) Contrast



Contrast is the combination of opposing elements e.g., opposite colors on the color wheel – blue / orange. Contrast in tone or value – light / dark. Contrast in direction – horizontal / vertical.

d) Scale



Using the relative size of elements against each other can attract attention to a focal point. When elements are designed larger than life, scale is being used to show drama.

e) Rhythm and repetition



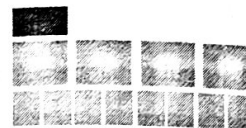
When one or more elements of design are used to create organized movement, it creates a feeling or a rhythmic pattern. Repetition is the use of similar patterns to make the focal point clearly visible.

f) Dominance / Emphasis



Dominance is created by contrasting size, positioning, color, style, or shape. The focal point should dominate the design with scale and contrast without sacrificing the unity of the whole.

g) Hierarchy



It is the arrangement of elements in their order of significance starting from the most important to the least.

4.7 Factors to be considered while designing buildings

a) Function

The purpose of the building greatly influences design. For example, an auditorium requires open and wide space to accommodate hundreds of audiences and should have large entry and exit gates.

b) Aesthetics

Buildings which need to attract people like multiplexes, shopping complexes, restaurants and resorts should have eye-catching design. On the other hand, warehouses and petrol stations need not be aesthetically appealing.

c) Environmental sustainability

Buildings must be designed to cope with the external environment. Careful orientation of the structure and proper choice of materials can ensure naturally comfortable atmosphere in the interiors at all seasons. For example, accurate positioning of glass rooms to take advantage of the sun warmth for winter heating and use of large overhanging eaves to shade the glass in summer could minimize the cost of cooling.

d) Availability of tools and materials

Available tools must be sufficient for construction so as to expedite the construction and minimize unnecessary cost. The use of local materials results in better blending of the structure with the surrounding.

e) **Safety**

Safety must be a priority in design. Structural safety can be achieved by the choice of symmetrical and regular building shapes and use of strong materials to sustain damage even during earthquakes. Safety can be ensured during construction by addressing safety issues and plans to all workers on a daily basis, by efficient supervision of scaffolding setups and backup harnessing whenever needed. Safety of occupants is crucial and available codes of practice must be followed, especially regarding the sill level of windows, height of parapets, provision of handrails etc.

f) **Trend**

The designer must be well acquainted with the current trends while designing buildings. Vastu, which stems on the theme of driving the available energy in the building towards positive effect on the occupants, is given due significance while planning the location of rooms, temple, staircases, lifts and other architectural features.

4.8 Standards to be followed while designing buildings in Nepal

The standard to be followed are,

a) **Staircase**1. **Width**

- Apartment = 1000 mm
- Auditorium (<500 capacity) = 1500 mm
(>500 capacity) = 2000 mm
- Hospitals = 2000mm
- Warehouse = 1250 mm
- Educational = 2000 mm
- Residential = 800 mm
- Cinema (<500 capacity) = 1500 mm
(>500 capacity) = 2000 mm

- Public assembly (>2500 occupants) = 2500 mm
 - Access to attics and terraces = 600 mm
2. **Tread**
 - Minimum = 250 mm excluding nosing
 3. **Riser**
 - Maximum = 175 mm for buildings
= 190 mm for internal staircase of apartment
 - Numbers = Maximum of 15 per flight
 4. **Handrail**
 - Minimum = 900 mm above the tread
 5. **Exit**
 - Maximum travel distance on the floors to exit shall not exceed 30 m for all types of buildings.
 - Exits shall be illuminated and free from obstructions.
 - Exit door inclusive of frame shall be 1m X 2m.
 - Exit doors to staircases and public passages shall open outwards and not obstruct landings or passages when open.
- b) **Lighting and ventilation**
- All habitable rooms shall have admission of light through external wall openings not less than $1/10^{\text{th}}$ of floor area.
 - No portion of the room shall be considered naturally lighted if it is more than 7500 mm from the opening assumed for lighting that portion.
 - For natural ventilation, openable exterior openings not less than $1/20^{\text{th}}$ of the floor area shall be provided.
 - For water closets and bathrooms, minimum size of ventilation shaft shall be 1 sq. m.
 - When natural lighting and ventilation requirements aren't met, artificial lighting and mechanical ventilation must be used.

c) Lifts

- Lift shall be provided for all buildings more than 15000 mm in height.
- Not more than 4 lifts shall be provided per bank.
- Shafts for lift shall be enclosed by walls having fire resistance of two hours.
- Lift wells that extend more than two floors shall be ventilated to outside air through openings not less than 3.5% of shaft area.
- In case of failure of normal electric supply, the electric supply for lift shall automatically trip over to an alternate power source.

d) Requirements for the physically disabled

- At least one primary entrance to a building shall be usable by the physically disabled and shall be on the level that would provide access to elevators where provided.
- Access ramps for wheelchairs shall not have gradients exceeding 1:12. Level platforms shall be provided at changes of directions and maximum 1800 mm flight. The minimum width of wheel chair accessible ramps shall be 900 mm for apartments and residents and 1000 mm for other buildings. Hand rails are provided when total rise exceeds 600 mm.
- The area accessible by wheel chair shall have a flush threshold and openings with minimum clear width of 775 mm.

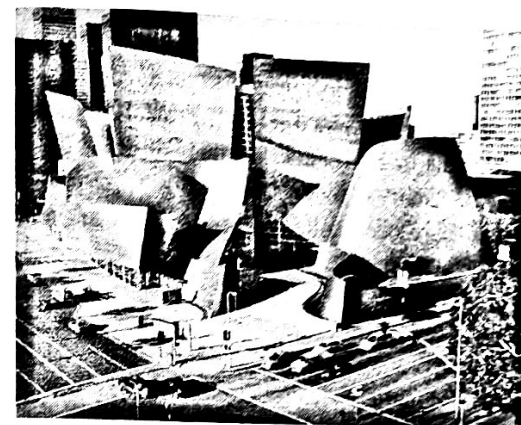
e) Parapet

All accessible roof terraces and balconies shall have parapet and handrails not lesser than 1000 mm in height.

4.9 Contemporary world architects and their works

a) Frank Gehry

A Canadian-American architect born on February 28, 1929, Frank Gehry is famous for his deconstructive forms and unique use of materials.



Walt Disney Concert Hall

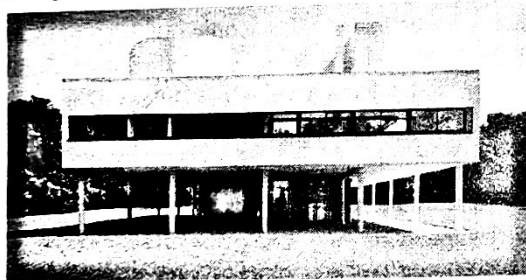
Deconstructivism is a postmodernist architectural style that is characterized by freedom of form and exhibition of complexity in a building rather than strict attention to functional concerns and traditional design elements such as proportion, symmetry, right angles and grids. By the late 1980s, two-dimensional construction plans were no longer adequate for realizing Gehry's increasingly complex geometric forms. So, he adapted CATIA (Computer Aided Three-Dimensional Interactive Application), a software originally created to design airplanes and ships, with which he created complex iconic buildings such as the Olympic Village in Barcelona, Nationale Nederlanden Building in Prague and the Guggenheim Museum in Bilbao. This established him as the pioneer to use digital technology in complex architectural modelling. In 2002 he founded Gehry Technologies, dedicated to the research and development of new software and programs to aid design. This new company created an add-on to CATIA called Digital Project, which is now used by architects all over the world.

Gehry has experimented with different materials throughout his career by engaging in multiple tests to ensure the material's safety and effectiveness. In his early days, he used economical, industrial materials such as galvanized chain-link fencing, corrugated metal sheeting, cardboard, and asphalt in unconventional ways. He gained popularity for his metal cladding designs such as the use of flexible stainless steel in the facade of Walt Disney Concert Hall in Los Angeles and the use

of titanium sheets in the facade of Guggenheim Museum in Bilbao. His other notable works include Der Neue Zollhof in Dusseldorf, Experience Music Project in Seattle, DG Bank Apartments in Berlin and Marques de Riscal Vineyard hotel in Elciego. Gehry's models, drawings, sketches and furniture designs have been collected in important museums all over the world and presented in numerous exhibitions. He was also a Pritzker Architecture Laureate in 1989.

b) Le Corbusier

Charles-Édouard Jeanneret-Gris, who was better known as Le Corbusier (1887 to 1965 AD), was a Swiss-French architect, designer, painter, urban planner and writer. He was one of the pioneers of modern architecture. His career spanned five decades largely towards dedication of providing better living conditions for the residents of crowded cities. His buildings have been constructed throughout Europe, India, and America. His notable works include Maisons Jaoul in France, Unite d'Habitation in Marseilles, Immeuble Clarté in Switzerland, Villa Savoye in France, Villa Schwob in Switzerland, The Chandigarh Master Plan along with the Capitol complex and countless more.



Villa Savoye

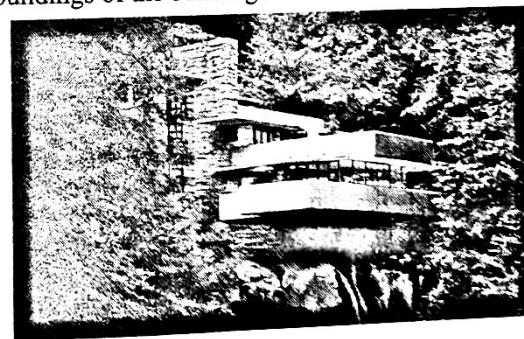
During his career, Le Corbusier developed a set of architectural principles that dictated his technique, called "the Five Points of a New Architecture". These were:

- Pilotis – Pilotis or piers are supports such as columns, pillars, or stilts that lift a building above ground or water. The replacement of supporting walls by a grid of reinforced concrete columns that bears the load of the structure is the basis of the new aesthetic.

- Open ground plan – The absence of supporting walls means that the house is unrestrained in its internal usage.
- Free façade – By separating the exterior of the building from its structural function the façade becomes free.
- Horizontal window – The façade can be cut along its entire length to allow rooms to be lit equally.
- Roof garden – The flat roof can be utilized for a domestic purpose while also providing essential protection to the concrete roof.

c) Frank Lloyd Wright

Frank Lloyd Wright (1867-1959) was an American architect noted for his prairie-style buildings and organic influences. He believed in designing such structures which harmonize with their environment, their purpose and time, a philosophy called organic architecture. The introduction of the word "organic" in his philosophy was an extension of the teachings of his mentor Louis Sullivan who famously quoted that "form follows function", still a popular slogan of modern architecture. Wright changed the phrase to "form and function are one". So, his organic architecture respects the harmonious relationship between the form / design and the function as well as the surroundings of the building.



Falling water residence

He is also contributed to pioneering the Prairie style Architecture characterized by horizontal lines, flat or hipped roofs with broad overhanging eaves, solid construction and restraint in the use of decoration. His most renowned among such works is the Robie House in Chicago which was built in 1910, seventeen years after

establishing his practice and towards the end of his exploration of the Prairie Style. He used simple building materials- brick, wood and glass without distorting their natural properties. The projecting cantilevered roof eaves, continuous bands of art glass windows and pointed brickwork with distinct cream coloured horizontal lines and brick-coloured small vertical joint create an impression of continuous horizontal linings in the building.



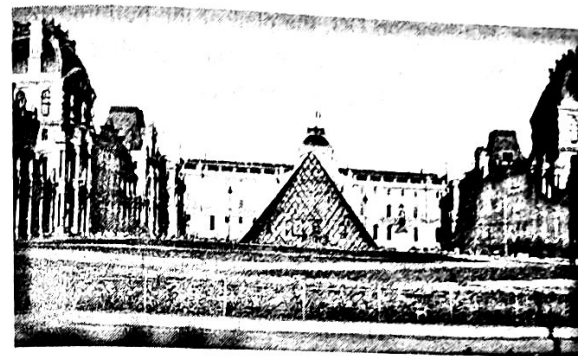
Robie House, Chicago

The basic principles of his design are as follows:

- i) Organic colours
- ii) Simple geometric shapes
- iii) Integration of building with natural surroundings
- iv) Strong horizontal lines
- v) Hidden entries

He designed 1141 homes and buildings, of those 532 were constructed during his almost 70 year long career. He had a global impact on modern architecture influencing design styles not only in America but also in Europe and Asia. His notable projects include The Guggenheim Museum in New York city, Robie House in Chicago, Unity Temple in Illinois and Falling Water Residence in Mill Run, Pennsylvania.

d) **Ieoh Ming Pei**



Le Grand Louvre

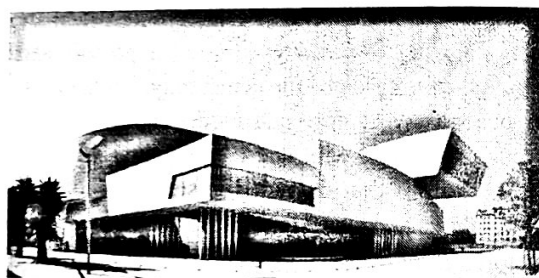
Ieoh Ming Pei, born on April 26, 1917 in Guangzhou, China, studied architecture in the United States. The Chinese architect is known for his unique use of geometric forms and incorporation of Chinese influences into his work. He is often described as a modernist but according to him the style in which an individual building is going to be designed is less important than its impact on the life of people and the community. Unlike most architects who have a stylist approach to design, he had an analytical approach to design with due consideration of time, place and purpose. So, his designs varied in style; his concepts were too individualized and contextual, due to which there are no specific principles of his design.

Pei is also known for combining traditional architectural elements with progressive designs based on simple geometric patterns. This is illustrated by his famous redesign of Louvre Museum (originally Royal Palace), in which he designed a steel and glass pyramid in the courtyard which provided a concealed underground entrance to the previously separate three wings of the museum. His use of simple geometric forms are exhibited in several of his works. In the Bank of China Tower, Hongkong, the first skyscraper to exceed 1000ft. height outside the US, he created a complex geometry in a simple square plan of the building with four inward-facing triangular quadrants which rose to different heights. In the 7 storey tall Dallas City Hall, he incorporated an inverted triangular section design to allow lesser area in the lower civic space floors and larger area in the upper

government office floors. In the National Gallery of Art East Building, Washington DC, the plan of the building comprised a larger isosceles and smaller right angled triangle that subsequently created triangular and diamond-shaped spaces inside.

Pei is also remembered for his magnificent use of glass in his designs, which can be demonstrated from his glass curtain walls in the Bank of China Tower and the Rock and Roll Hall of Fame in Cleveland, glass pyramid in the Le Grand Louvre and glass atrium in the National Gallery of Art East Building. His other notable projects include John F. Kennedy Presidential Library and Museum in Boston, Mudam Museum in Luxemborg, Museum of Islamic Art in Doha and the Suzhou Museum in China. He was also a Pritzker Architecture Laureate in 1983.

e) Zaha Hadid



The National Museum of the 21st century Arts

The first woman architect who has won the Pritzker Architecture prize (in 2004) is the Iraq born Zaha Hadid (1950-2016) who later became a British citizen. She learned about abstract art and architecture from the Architectural Association in London. Like Frank Gehry, she is also famous for her deconstructive forms. The use of unconventional and circular forms in her designs even led her to be nicknamed "The Queen of the Curve" by the British media. Hadid's forms are characterized as futuristic, unconventional, daring and artistic. She is considered the most imaginative architect among her colleagues. She has designed about 950 projects out of which only 80 have been completed. Her noted projects are MAXXI – the National Museum of the

21st century Arts, Kusunok Villa in Zurich, Bergisel Ski Jump in Innsbruck, Vitra Fire Station in Germany and the Opera House in Guangzhou.

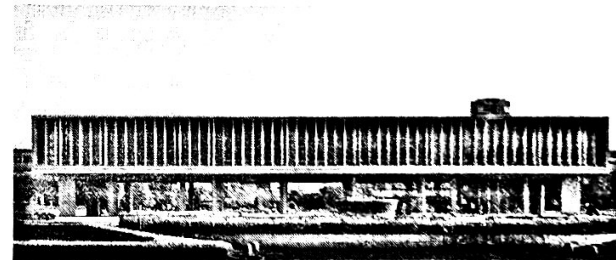
f) Philip Johnson

The American architect is renowned for his amazing use of glass, steel and later crystals. His notable projects are Seagram Building in New York city, IDS Center in Minnesota, Glass House in Connecticut and The Crystal Cathedral in California.



Seagram Building

g) Kenzo Tange



Peace Center in Hiroshima

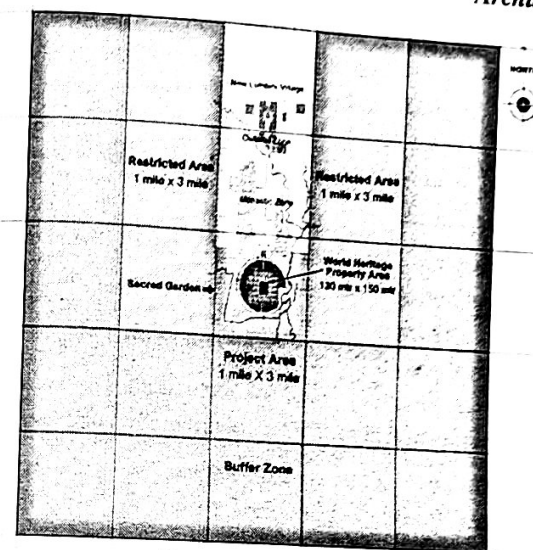
Kenzō Tange (1913 to 2005) was a Japanese architect, and winner of the 1987 Pritzker Prize for architecture. He was one of the most significant architects of the 20th century, combining traditional Japanese styles with modernism. Tange's best-known buildings are the two national gymnasiums erected in Tokyo for the 1964 Olympic Games (the first to be held in Asia). The roofs

of these two circular buildings indelibly recall the massive forms of traditional Japanese temples, but they are, also, altogether contemporary in form and technique. These roofs, suspended by cable from massive concrete pillars (a single pillar for the smaller structure, a pair for the larger), consist of prestressed steel nets onto which are attached welded steel plates. The interiors are also bold and elegant with welcoming open spaces illuminated by a combination of artificial and natural light.

From the mid-1960s onward Tange received widespread international attention and commissions. His firm, called the Urbanists and Architects Team (URTEC), provided the master plan (1965) for the reconstruction of Skopje, Yugoslavia, after its devastation by an earthquake and did important planning studies for cities and regions in Africa, the Middle East, and Europe as well as in Japan.

His notable works include Peace Center in Hiroshima, The Ise Shrine in Ise, Japan, Supreme Court Building of Pakistan, Osaka Exposition and Tokyo Olympic arenas. Tange was involved in the replanning of the city of Hiroshima after its destruction by the atomic bomb on 6 August 1945. At the heart of the revived city, Tange built a peace centre, raised on stilt-like columns, faced by a monument that was a blend of ancient forms and the latest structural technology. This peacetime fusion of a traditional tomb and a concrete parabola was very much a symbol of new Japan, resolutely looking to the future while proudly recalling the best of its past.

He has also worked in Nepal for the preparation of a Master Plan for Lumbini. The Secretary-General of the United Nations, on his visit to Nepal in April 1967, proposed the development of Lumbini into a major center of pilgrimage. This was followed by a UNDP consultant mission in December 1969, which led to a report that established the basis for further planning around Lumbini.



Kenzo Tange Master Plan
5 mile x 5 mile

In 1970, the International Committee for the Development of Lumbini (ICDL) was set up comprising initially of 13 members and later expanded to 16 member states. The initial member states were Afghanistan, Cambodia, India, Indonesia, Japan, the Lao People's Democratic Republic, Malaysia, Myanmar, Nepal, Pakistan, Singapore, Sri Lanka and Thailand. Later, Bangladesh, Bhutan and Republic of Korea also joined. At the national level, the Lumbini Development Committee was formed. ICDL initiated the preparation of the Master Plan for Lumbini, which was conceptualized by Kenzo Tange starting from 1972. The Kenzo Tange Master Plan was finalized and approved in 1978.

The Kenzo Tange Master Plan covers an area of 5x5 miles with the central square mile being the Sacred Garden within which is the UNESCO World Heritage Property. Of the Master Plan, the 1x3 mile area which includes the following three zones: New Lumbini Village, Cultural/Monastic Zone and the Sacred Garden - are part of the Lumbini Project Area.

i) The Sacred Garden Zone

The Sacred Garden will include the area related to the birth of Gautam Buddha and will reflect the great ideals of peace,

compassion, purity and brotherhood. It will include the Maya Devi temple, Asoka Pillar, various stupas, chaityas and old remains of garden and trees.

ii) **The Monastic Zone:** It is divided into East and West Monastic Zones.

East Monastic Zone is reserved for construction of Theravada monasteries from various countries. Burma and Nepal have already completed the construction of their monasteries. Others have either started the construction or have reserved the site for future construction. Beside the monasteries a Vipassana meditation centre also will be constructed in this zone.

West Monastic Zone is dedicated to construction of about 15 Mahayana tradition monasteries from all over the world. A magnificent Chinese monastery is already complete and the rest are either under construction or will start constructing in near future.

About 49 stupas and Viharas (monasteries) would be constructed by various individuals, associations and countries in monastic zone. In the middle of this area, there will be a road with Sal trees on both sides, a garden, an open stage, court yards etc.

iii) **The New Lumbini Village Zone**

This zone is purely allocated for physical facilities like hotels, pilgrims' inn, post and telegraph offices, a hospital and a school. There are also provision for construction of a museum, a library, an International Buddhist Research Centre and a Tourist information centre. Also within this zone, the highest World Peace Pagoda of Asia has already been completed by Japanese Buddhists.

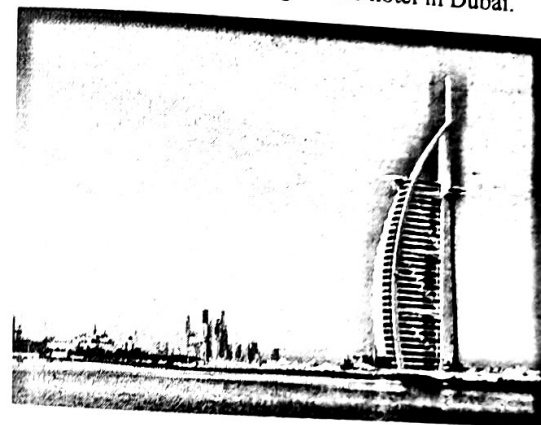
The three zones in the 1x3 mile area of the Kenzo Tange Master Plan are connected by a canal in the central link. The remaining area outside the Lumbini Project Area within the 5x5 mile zone is the Buffer Zone, which protects the three zones in the 1x3 mile area.

Implementation of the Master Plan commenced in 1978 and was initially scheduled to be completed by 1985. Progress was,

however, slower than anticipated. In 1985, Lumbini Development Trust (LDT) was established to take on the challenge of managing and implementing the components of the 1x3 mile Lumbini Project Area in accordance to the Kenzo Tange Master Plan.

h) **Tom Wright**

The British architect born in September 18, 1957 is known to design distinctive buildings which are completely different compared to many other buildings around the world. His designs and thoughts are very individual as he creates masterpieces as well as functional buildings for the world to experience. He has created some of the world's most renowned buildings such as the Burj Al Arab, the most recognizable hotel in Dubai.



Burj Al Arab

In the quest of designing a building to become the symbol of Dubai, Tom Wright came up with the idea of the building to look like a giant sail with inspiration from a modern yacht sail so as to reflect Dubai's seafaring heritage. The aesthetically pleasing lighting on the exterior of Burj Al Arab also flourished the nightlife in Dubai as a cultural aspect.

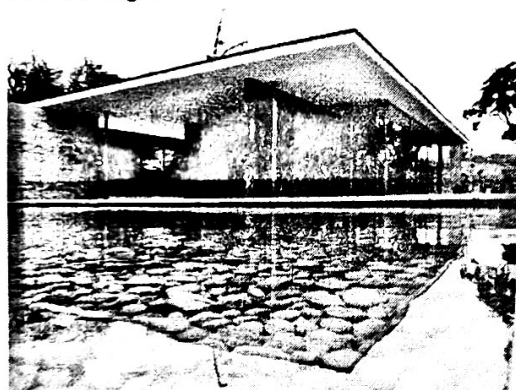
His other notable works include Ribbon of Light in Tehran, Kazan Zoo in Russia, Opal Hotel in Seychelles, Incheon Masterplan in South Korea, Landmark Tower in Cyprus and the Centaurus in Islamabad.

- i) Ludwig Mies Van der Rohe
The German-American architect is one of the pioneers of modern architecture. Mies is known for his minimalist and less is more approach to architecture and his forward thinking of using plate glass and structural steel to divide interior space.

The basic characteristics of his works are:

- Simple rectangular forms
- Open, flexible plans and multi-functional spaces
- Widespread use of glass to bring the outside in
- Mastered steel and glass construction
- Exposed and very refined structural details

His notable works are Barcelona Pavilion, Farnsworth House in Illinois, New National Gallery in Berlin, Seagram building in New York, Lake Shore Drive Apartments in Illinois and Crown Hall in Chicago.

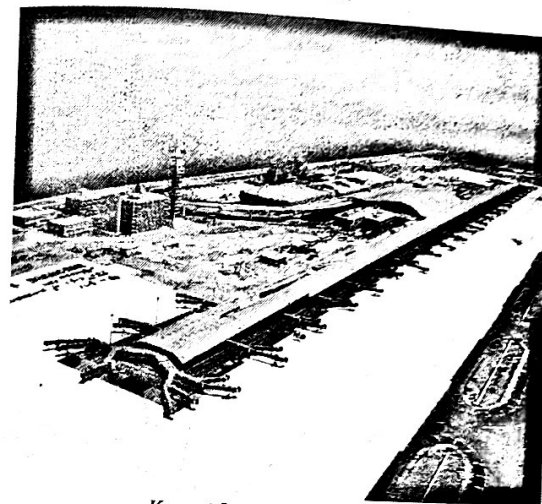


Barcelona Pavilion

- j) Renzo Piano

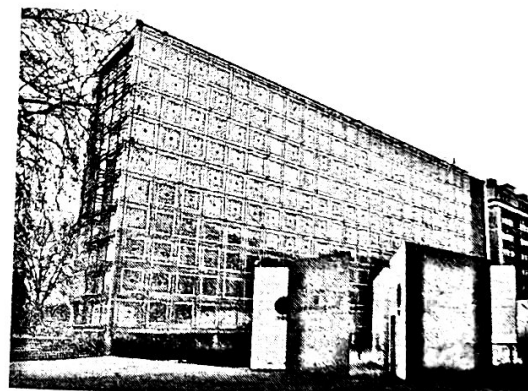
Renzo Piano is often called a High Tech architect as his design showcases technological shapes and materials. High tech buildings are often called machine-like; steel, aluminum and glass combine with brightly coloured braces, girders and beams. Many of the building parts are prefabricated in a factory and assembled later. The support beams, duct work and other functional elements are placed on the exterior of the building, where they become the focus of attention. The interior spaces are open and adaptable for many uses.

The notable projects of this Italian born architect are the Shard in London, NEMO Science Center in Amsterdam, Centre Pompidou in Paris, The New York Times building in New York, San Nicola Stadium in Italy, Columbus International Exposition in Italy, Menil Collection Museum in Texas and Kansai International Airport in Osaka.



Kansai International Airport

- k) Joan Nouvel

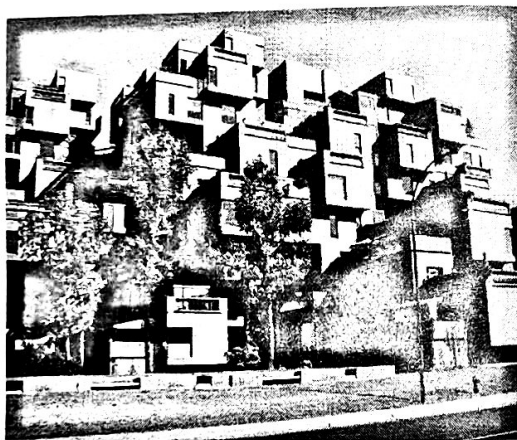


Arab World Institute Paris

The French born architect is famous for his innovative architectural concepts. His works include Arab World Institute in Paris, Denstu Building in Tokyo, Zlaty Andel in Prague,

Guthrie Theatre in Minneapolis, Le Louvre in Abu Dhabi, Copenhagen Concert Hall in Copenhagen and Seguin Island masterplan in Paris. He was also the Pritzker Prize Laureate in 2008.

- 1) Moshe Safdie
Born in 1938, he is an Israeli / Canadian architect, urban designer, educator, theorist and author. Embracing a comprehensive and humane design philosophy, Safdie is committed to architecture that supports and enhances a project's program; that is informed by the geographic, social, and cultural elements that define a place; and that responds to human needs and aspirations. Safdie has completed a wide range of projects, such as cultural, educational, and civic institutions, neighborhoods and public parks, mixed-use urban centers and airports, and master plans for existing communities and entirely new cities around the world.



Habitat 67

Safdie has worked with a wide range of clients, including municipal entities and government agencies, colleges and universities, private developers, and non-profit organizations and civic institutions. Many of his firm's buildings have become beloved regional and national landmarks, including Exploration Place Science Center in Wichita, Kansas, Salt Lake City Public Library in Utah, Peabody Essex Museum in Massachusetts,

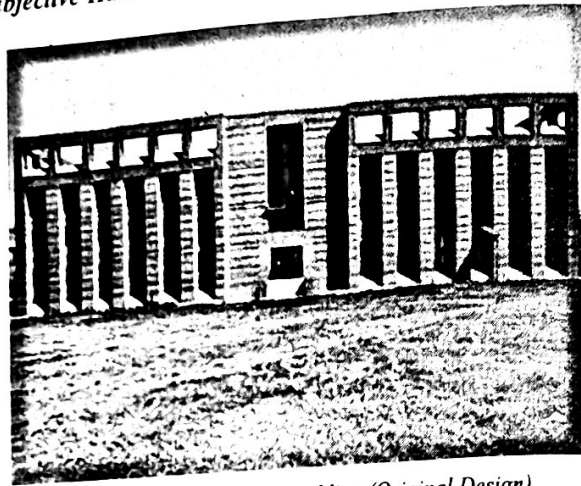
Springfield Federal Courthouse in Massachusetts, Skirball Cultural Center in Los Angeles, California, Lester B. Pearson International Airport in Toronto, Canada, the National Gallery of Canada and Yad Vashem Holocaust Museum in Jerusalem, Israel. His finest projects include Habitat 67 in Montreal, Marina Bay Sands in Singapore, the National Campus for the Archeology of Israel in Jerusalem and Khalsa Heritage Memorial in Punjab.

In addition to his projects, Safdie has written several books, most notably, *Beyond Habitat* (1970), *For Everyone a Garden* (1974), *Form and Purpose* (1982), *Jerusalem: The Future of the Past* (1989) and *The City After the Automobile* (1997).

- m) Louis Kahn

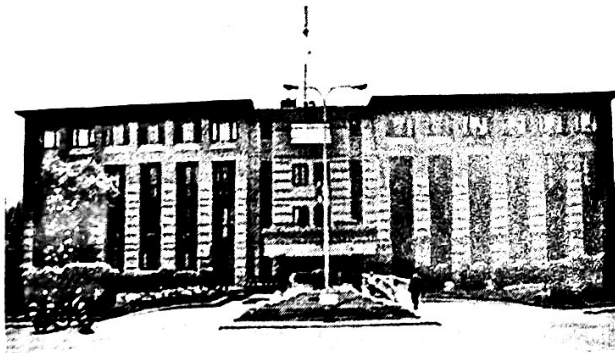
In Louis Kahn's (1901-1974) personal philosophy, form is conceived as formless and unmeasurable, a spiritual power common to all mankind, which transcends individual thoughts, feelings and conventions. Earlier works of Kahn had a traditional international style of architecture. However, in the middle of his career, Kahn turned his back on this traditional approach and pursued innovation by redefining the use of structure, light, form and space. He is credited for the re-introduction of various concepts which most of the modern architects had deserted like centralized spaces, using extensive geometric principles and demonstration of solid wall strength. Kahn believed that natural light brought architecture to life. His works demonstrate wide-scale implementation of sunlight through different kinds of interesting windows and openings. Kahn is also known to have used brick and concrete extensively and his innovative usage of these materials demonstrated his talent to the world.

His notable works include Yale University Art Gallery in Connecticut, Salk Institute for Biological Studies in California, Richards Medical Towers in Philadelphia, Indian Institute of Management in Ahmedabad, Kimbell Art Museum in Texas and Shaheed Suhrawardy Medical College and Hospital in Dhaka.



Nepal Family Planning Building (Original Design)

In Nepal, Louis Kahn designed the Nepal Family Planning and Maternal Child Welfare building. The building is a symmetrical composition of exposed brick piers interspersed by vertical strips of wooden windows. The building was topped off by a one-store high exposed brick parapet with deep punctures enclosing large roof terraces-courtyards in the sky. Unfortunately, despite protests from Nepali architects not to play around with the original design, the current resident of the building, the Ministry of Health went ahead and converted its rooftop into office space, and covered it with an ugly corrugated iron roof.



*MOH (previously Nepal Family Planning Building)
Design after transformation*

4.10 Architectural landmarks in Nepal

a) Changunarayan temple

It is considered to be the oldest temple of Nepal. The temple in the eastern fringes of Kathmandu reflects artistic achievement and skills in architecture. The two storey roofed temple rests on a high plinth of stone. The ten incarnations of Lord Vishnu and other idols are carved in the struts that support the roof. It is surrounded by sculptures and arts related to Lord Vishnu. There are four entrance ways that opens to the open courtyard in which there are small temples of Lord Shiva, Ashta Matrika, Chhinnamasta, Kileshwor and Krishna along with the main temple. The entrance doors are gilded with carvings of Nāaga (snakes). On the main entrance gate (i.e. western entrance gate), there are Chakra, Sankha, Kamal and Khadga all at the top of a stone pillar. The stone pillars have an inscription in Sanskrit dating back to the Lichhavi dynasty.

The temple is undergoing renovation works after suffering partial damage due to the earthquake in 2015.

b) Swayambhunath

Swayambhunath is another ancient landmark. It is a stupa with a dome as the base above which is a cubical structure painted with eyes of Buddha looking in all four directions. It was relatively unaffected by the earthquake 2015.

c) Kasthamandap

Kasthamandap temple is believed to be built with the trunk of a single tree. It is the epitome of Thakuri dynasty in terms of architectural expression. The building was completely destroyed in the Earthquake 2015 and is in the state of reconstruction.

d) Durbar Square

The Kathmandu, Patan and Bhaktapur Durbar Square were built in the Malla dynasty. The architectural craftsmanship in the form of wood and metal is clearly demonstrated in the overhangs of Pagoda, in the detailing of facades and opening levels of temples in the Durbar Squares.

During the earthquake in 2015, many temples in the Durbar Square were destroyed. In Kathmandu Durbar Square, including Kasthamandap, Maju Dega temple, Narayan Vishnu temple, Trailokya Mohan temple, Chasin Dega and Kakeshwar Temple suffered collapse whereas King Malla's column, Shiva Parbati temple, Gaddi Baihak and Basantapur tower were partially damaged. The iconic Dharahara just outside the Kathmandu Durbar Square also collapsed due to the earthquake. However, Kumari House, Taleju temple and Jannath temple in the Durbar Square survived.

In Patan Durbar Square, the majority of temples survived though nearly all temples suffered some damage. The Hari Shanker temple got completely destroyed whereas the Mahaboudha temple, Chyasim Dewal, Jagan Narayan temple, Viswanath temple, Bhimsen temple and Keshav Narayan Chowk were partially damaged. However, in the north the Golden temple, in the south the Machchhendranath temple and in the west Kumari house are relatively unscathed. Likewise the Kumbeshwar temple complex survived though the main temple is leaning slightly.

In Bhaktapur, the iconic Nyatapola temple and most of the Taumadhi and Dattatreya square area remained unscathed. However, Bhaktapur Durbar Square lost some precious temples like the Vatsala Durga temple and the Fasidega temple. Other temples which suffered mild damage include Til Mahdavi Narayan temple, Rameshwar temple, Taleju temple and National Art museum.

e) Works of foreign practitioners

The valley opened up for modern development in 1950s. Robert Weisse designed several prominent architectural landmarks like the Annapurna Hotel, The Yellow Pagoda Hotel and the Nepal Army headquarters. Pruscha came to Nepal and contributed with design of Taragaon hotel and Institutional building CEDA for Tribhuvan University. The Family Planning Center designed by Louis Kahn is also famous.

f) Other modern architectural landmarks

Nepal witnessed the blending of heritage with modern expression of hotels like Taragaon Hyatt Regency, Fulbari Resort and Dwarka Hotel in the earlier parts of 2000 AD. Some other landmarks are the Narayanhiti Palace, ICIMOD building, Mountaineering Museum in Pokhara, Krishna Tower and Laxmi Bank, Kathmandu.

4.11 Conservation of historic buildings

Historic conservation

Historic conservation is an endeavor that seeks to preserve, conserve and protect buildings, objects, landscapes or other artifacts of historical significance. Conservation carries a wider meaning and embraces the various kinds of treatment that are given to any monument to lengthen its life. The spinal concept of conservation is to retain the originality of the monument to the greatest possible extent. Everything around us will either perish or be transformed into a new form, sooner or later. Our past is our roots and it needs to be respected. The cultural relics of our ancestors have been renowned all over the world for its fine craftsmanship. It's the duty of the current generation not to act according to whims of fashion and follow the popular trend but to look after and preserve the objects of heritage.

Modern phase of historic conservation in Nepal and major role players

Nepal entered the modern phase of historic conservation after 1950s. After the exposure of Nepal to the rest of the globe following the 50s, changes began to surface in all the national avenues of the country. The establishment of Department of Archaeology, the beginning of the external collaboration, the implementation of the Kasthamandap Renovation Project, the Hanuman Dhoka Conservation Project and the Bhaktapur Development Project were some milestones achieved after the 50s. The Kasthamandap Renovation was executed by the Department of Archaeology, the Hanuman Dhoka Conservation was done by UNESCO/UNDP collaboration whereas Bhaktapur Development

Project was possible with HMG / FRG co-operation. The major role players are:

a) Department of Archaeology (DOA)

This department was established in the year 1952 but received necessary legal powers in 1957 only after the promulgation of Ancient Preservation Act. This Act established criteria for the identification of objects of archaeological, historical and artistic value. It also made provision for providing protection to such objects. According to the Act, self-initiated excavations, acquisition of monuments, pilferage of statues and images were all liable to be punished. The Department cares for about 5% of monuments, which do not enjoy the privilege of owning the Trusts established for their protection.

b) The Guthi Corporation

This Corporation was established through Guthi Corporation Act 1964. It was amended later in the year 1972. It has, in paper, lots of land in its possession, e.g. 88000 bighas in the Terai or lowlands and 400000 ropanis in the highlands, midlands and the valleys. Besides it has many jewels and precious stones. Moreover, it has many chhut guthis which are private trusts established by the Government with the families. After its establishment, an organization known as Guthi Jirnodhar tatha Nirman Samiti or Trusts Restoration and Construction Committee was formed under the joint collaboration of the Department of Archaeology and the Trust Corporation where the Department provided the expertise and the Corporation the necessary fund. Many monuments were conserved with this united approach. However, this did not continue for long and these organizations started to function individually.

c) The Valley Reform Committee

This committee was formed in 1956 and conserved so many monuments on the occasion of the Coronation of the then King Mahendra. But, the conservation work was not done very scientifically understanding the norms of conservation and there was a loss of artistic and archaeological merit during conservation in certain places. But what was encouraging was

the second life given to the monuments which were in advanced stage of decay.

d) The Village Council

Through the Act of 1961, it was furnished with the responsibility of carrying out the conservation works of all the public ponds in the periphery of bridges, temples, rest houses etc.

e) Remote Area Development Committee

It carries out special crash programs in the remote area of the country. It had completed the restoration works of the Buddhist monasteries, some 136 of them till the late eighties.

f) Agricultural Development Banks

This bank also carried out conservation works of some of the historic monuments, most notable of them being the conservation of the temple of Muktichhetra.

g) Indian Cooperation

In 1960, Mr. A. Ghosh made a study of different aspects of conservation scenario in Nepal and submitted a report to His Majesty's Government wherein he stressed the need for single agency to tackle the problems of conservation of the monuments in the country. He made it clear that such responsibility for conserving the monuments should be with the Department of Archaeology. He was the Director General of Archaeology in India. In 1970, Dr. N.R. Banerjee, archaeological advisor under the Indian Co-operation Mission, submitted a report on Preservation of Monuments in Nepal wherein he recommended the urgency of the preparation of an optimum list of the monuments in terms of the various architectural styles existing in the country. Furthermore, he also recommended stopping the flow of traffic in the three Palace Squares of the valley. His report also recommended prevention of the erection of new structures in such historic areas.

h) UNESCO Assistance

Nepal made use of UNESCO assistance for the first time in 1963, when an Expert Mission consisting of Mr. Paor made a

detailed study of the functioning of Department of Archaeology, urged the Department to carry more technical responsibilities rather than administrative and presented several advice and recommendation. In another Mission, Mr. C Jest stressed the need to make classification and organization of the cultural heritage and site protection by the provision of appropriate legislation as well as the preservation and the presentation of such objects in a proper museum. In 1968, there were Missions led by J. C. Pallaco and E.A. Conally who gave suggestions for the development of cultural tourism in the country. In 1970, Miss Giselle Hyvert was tasked to set up a Conservation Laboratory to assist the preservation and restoration of monuments. Accordingly, a laboratory was established under the Department of Archaeology in 1975. In 1970, there was another Mission under John Sanday to study and make recommendations on the restoration of the Hanuman Dhoka Palace. Following his recommendations, the restoration work of this project was taken up. It also trained a group of craftsmen who worked on the project. This project started in 1970 but its last phase was completed only in 1983. UNESCO / UNDP deputed Prof. Sekler to advise the Government of Nepal on identifying approaches to preserving the historic urban area in Kathmandu Valley, with special emphasis on cultural heritage. He emphasized on collaborating with outside agencies and public awareness programs. His proposal of establishing a documentation center was quickly implemented through the help of UNESCO, the Austrian Government and the JDR third fund resulting the publication of a Protective Inventory of the Kathmandu Valley in two volumes. Next, a team of 8 consultants was sent by UNESCO, this time to make the Master Plan of Kathmandu Valley. Accordingly, the document was prepared and handed to the government in 1977. The document considered all the relevant factors like the cultural heritage, its general characteristics, scope of preservation, general and specific recommendations, phased implementation programs and cost likely to be involved. Seven Nepali sites were then included in World Heritage List- Hanuman Dhoka Durbar Square, Patan Durbar Square, Bhaktapur Durbar Square, Swayambhunath,

Pashupatinath, Changunarayan and Bouddhanath. In 1978, there was a problem in the Swayambhu Hills according to which the Stupa was steadily settling. The government sought the assistance of UNESCO after which Mr. E. Kojan came, studied the problem and suggested to stabilize the hills by rock bolting and through the provision of proper drainage. Several other UNESCO personnel have been deployed for the conservation of historical monuments in Nepal.

i) The German Collaboration

The Government of Nepal requested the then Federal Republic of Germany to make a proposal for the urban renewal and the development of Bhaktapur, following the successful restoration of the Pujarinath, the priest's house. This was prepared by experts from Dramstadt University who were involved in the aforementioned restoration; they submitted the proposal to the Federal Agency for Economic Co-operation, West Germany. This Project was known as the Bhaktapur Development Project and was launched in 1974 following the signing of an agreement for bilateral co-operation between the governments of Nepal and Federal Republic of Germany. This project was very significant on account of its scale and it addressed the whole town, as against early conservation endeavor which were restricted to one or at the most a few monuments only.

j) The International Fund for Monuments

This is an international funding agency in the US which provided fund for the restoration of the monuments in the Gokarneshwar Mahadev complex in Gokarna.

k) Belgium Nepal Friendship Association

This association contributed towards the restoration of two of the Char Narayan temples in Banepa.

l) The Austrian Assistance

The Austrians have contributed towards the restoration of the historical palace in Patan Durbar Square.

4.12 Ethics of architects in professional practice

- a) Knowledge and skill
Members should strive to improve their professional knowledge and skill.
- b) Standards of excellence
Members should seek to raise the standards of aesthetic excellence, architecture, education, research, training and practice.
- c) Natural and cultural heritage
Members should help conserve their natural and cultural heritage while striving to improve the environment and the quality of life within it.
- d) Human rights
Members should uphold human rights in all their professional endeavours.
- e) Allied Arts and Industries
Members should promote allied arts and contribute to the knowledge and capability of the building industries as a whole.
- f) Conduct
Members should uphold the law in the conduct of their professional activities.
- g) Competence
Members should serve their clients in a timely and competent manner.
- h) Honesty and fairness
Members should pursue their professional activities with honesty and fairness.
- i) Dignity and integrity
Members should promote dignity and integrity of the profession and ensure that their representatives and employees conform to the Code of Conduct.
- j) Intern and Professional Development
Members should recognize and fulfil their obligation to nurture fellow professionals as they progress through all stages of their career.



Annex - I

A Glimpse of the Relevant Acts

1. Apartment ownership Act 1997

In the name of 'Ownership of Joint Housing Act, 2054 (1997)', this Act was authenticated and published in 22 December 1997. The Act has several provisions which are enlisted below.

a) Apartment building permit

An individual, organization or a company who wants to construct an Apartment Housing should take permission from the competent authority. For that, an application shall be written in prescribed format accompanied by the proposed map, structural design, area of land and description of ownership, distribution procedure of the apartment units, description relating to common area and facilities and operational plan of the joint housing building. If an application is complete and valid, the competent authority shall, after any other necessary inquiry, give permission to the applicant to build and operate the joint housing building. Apartment housing can't be constructed without receiving the legal permit.

b) Sale and transfer of apartments

Apartment can be sold for either full payment or by payment on installment. It can also be sold or be given for rental purpose. The ownership certificate should be issued in specified format and the ownership is transferred only when the buyer pays off the total amount. The new owner of the apartment unit can sell, dispose of, rent, or otherwise transfer his or her title to, or transfer possession thereof, to another person. The owner of the apartment unit needs to establish consensus with the developer or management committee for selling his apartment. But again, there is a provision that if the new owner has paid off the total amount of the apartment, the management committee is obliged to give the permission.

c) Common collective interests and obligations

The owner of any one of the apartment units can, without affecting the rights of the owner of any other apartment unit, enjoy the common facilities and areas such as corridor, lobby, staircase, fire escape, entry and exit points, basement, parking areas, gardens, temples, stores, solar, elevators, generator room, security guard room, dumping site, electricity, gas, water cooling and heating, air conditioning etc. There is also a provision that the common places or facilities can't be divided or partitioned. And, the owner is obliged to bear the cost percentage as per the rule for the management or maintenance of the common properties. In case if an owner is reluctant to bear his share of money, the management committee can prevent the owner from enjoying that service or facility.

Apartment Housing should have its insurance. And it is the duty of the founding members to manage, protect and maintain those apartment units. Incase if the apartment housing is completely damaged or demolished, all the owners of the apartment units will have proportional ownership over the land. And, if the apartment is partially damaged, the management committee or the founding members should have to repair it within the specified time.

d) Protection, care, repair and maintenance by housing management committee

If the developer sells or disposes of all apartment owned by him or her and if all apartment owners of any joint housing building express consent in writing to operate the joint housing building on their own, the developer body corporate shall not be able to carry out the protection, care, repair, maintenance and sanitation of the joint housing building and common area and facilities. Rather, the apartment owners shall form a management committee from amongst themselves for the protection, care, repair, maintenance and sanitation of the joint housing building and the committee itself shall determine the rules henceforth. The developer or committee may collect charges and fees from the apartment owners for the associated works.

e) Punishment

Construction of the Apartment housing without construction permit would be subjected to legal action. The construction company can be charged fine up to NRs. 100,000. The concerned authority can also issue order for demolishing such buildings. If a joint housing building gets damaged because of the fact that the building has not been built in consonance with the design approved by the competent authority and standards approved, such a developer shall be liable to a fine ranging from NRs. 100,000 to NRs. 500,000. Moreover, if anyone is injured from the damaged part of such apartment, he/she can claim the appropriate compensation from the developer.

2. Building Act 1998

This Act was authenticated and published on 2nd July 1998. It has the following provisions.

a) Formation of Building Construction Management Upgrading Committee

The Government of Nepal shall form a Building Construction Management Upgrading Committee for the consolidation of building construction works. The committee shall consist the Secretary of MOUD as chairperson, representatives of NPC, Ministry of Law, member secretary of Nepal Quality Standards Council, dean of Engineering Institute, joint secretary of MOLD, chief of Research Center for Applied Science and Technology and a maximum of three people nominated by the Government from amongst those who have special knowledge on building construction as members and the Director General of DUDBC as member secretary. DUDBC shall act as the secretariat of the committee.

b) Functions of the committee

The committee shall regulate building construction works in order to minimize possible loss to buildings from earthquake, fire and other natural calamities, formulate a building code to regulate construction works, conduct research for timely reforms in the building code, recommend the Nepal Quality Assurance Council to determine the quality of native or foreign materials

related with building construction and hold or cause to be held, assemblies or symposia for timely resolution of problems coming across in the course of the implementation of the building code.

c) Classification of buildings

The Act classified buildings in four distinct categories:

- Category A: Modern building to be built, based on the international state-of-the-art, also in pursuance of the building codes to be followed in developed countries.
- Category B: Buildings with plinth area of more than 1000 square feet, with more than 3 floors including the ground floor or with structural span of more than 4.5 m.
- Category C: Buildings with plinth area of up to 1000 square feet, with up to 3 floors including the ground floor or with structural span of up to 4.5m.
- Category D: Small houses, sheds made of baked or unbaked brick, stone, clay, bamboo, grass etc., except those set forth in the above categories.

d) Buildings to be built in consonance with building code

Any person, body or government body shall, in making a building, build it in consonance with the standards set forth in the building code. In so making a building, the building shall be built under the supervision of a designer, engineer or architect whose rank is at least the same as that of the designer who has certified the map.

e) Provision for design approval

The map and design submitted shall have to be certified by the following person that they are in conformity with the building code:

- In case of a building of Category A, the concerned designer
- In case of a building of Category B, a civil engineer or architect
- In case of a building of Category C, a person who has passed at least certificate level in civil engineering or architect from a recognized educational institute.

f) Power to supervise building construction

In the case of within the municipal area, the municipality, and in the case of within the village development area, the Urban Development Office may make supervision whether any person, body or governmental body has built a building in consonance with the standards prescribed by the building code or not. If, in making supervision, it is found that the prescribed standards have not been followed, as per approved, the supervising team may give necessary directives to the concerned person or body, and it shall be the duty of the concerned person or body to abide such a directive.

g) Punishment

If any person or body builds a building without getting its design approved or in a manner contrary to such approved design, the municipality or the Urban Development office, as the case may be, shall give order to immediately stop such construction and may even order complete demolition along with fine up to NRs, 50,000.

3. Town Development Act 1998

a) Formulation of TDC

The town development committee shall have the following members:

- A person designated by the Government of Nepal as Chairperson
- Chief District Officer or an officer designated by him / her as Member
- Chiefs of five district level offices, in maximum, of the Government of Nepal or corporate body owned by the Government of Nepal or the representative designated by the concerned Chief as Member
- One representative nominated by the district working committee of each nationally recognized political party as Member

- Five persons, in maximum, nominated by the Government of Nepal from among social workers of respective area who have rendered significant contribution in the development of local area as Member
- Chief of concerned local body or a representative designated by him as Member
- An employee designated by the Government of Nepal as Member-Secretary

b) Functions, duties and powers of the committee

The committee shall have the following functions, duties and powers:

- To formulate town planning in order to carry out physical development of town in an integrated manner by determining land use area for the development of town and providing services and facilities such as road, transport, electricity, drainage and sanitation.
- To set guidelines for institutions or local body upon prescribing condition or standard for the physical development of land.
- To prepare necessary project and to implement it in town planning area for proper development and conservation of religious, cultural and historical heritage subject to prevailing law of Nepal on ancient monument.
- To prescribe condition on construction and other activities to be done in forest, stream, riverside and water area for the protection of nature and environment of town planning region, and to perform accordingly.
- To prohibit the use of natural resources that causes adverse effect on nature.
- To prepare the project related to land development and building construction in the land use area as per town planning and to implement it.
- To carry out other acts as directed by the Government of Nepal from time to time as per town planning.

c) Operation of land development programs

The committee may operate the following land development programs to manage residential land in the course of making development of town in planned manner.

- To formulate project relating to service and facility in a part of town planning area with the participation of at least 75% local land owners and tenants and to operate guided land development program as per the project in the investment of the concerned body of Government of Nepal, corporate body, municipality or local people.
- To operate land pooling programs by integrating various units of land situated in any part of town planning area on the consent of at least fifty one percent land owner or tenants of the area and to arrange service and facility for the integrated land as per town planning, to recover expenses made to arrange such service and facility by selling developed sites and to return back the sites to the concerned owner or tenants on pro-rata basis.

d) Approval and operation of the planning of physical development

In case any institution intends to operate the physical development planning in the area where town planning has come into force, it shall take approval from the committee. After taking approval, the concerned institution shall operate the approved plan as per the terms and standards prescribed by the Committee.

e) Land development by local bodies

In case local body (municipality or VDC or DDC) intends to conduct land development program, it shall take approval from the Government of Nepal on the recommendation of the committee or equivalent.



Annex - II

A glimpse of the relevant codes for seismic design and detailing

1. NBC 105: Seismic design of buildings in Nepal

One of the key aspects addressed by this code is the analysis for the design earthquake actions. This shall be in accordance to one of the following methods:

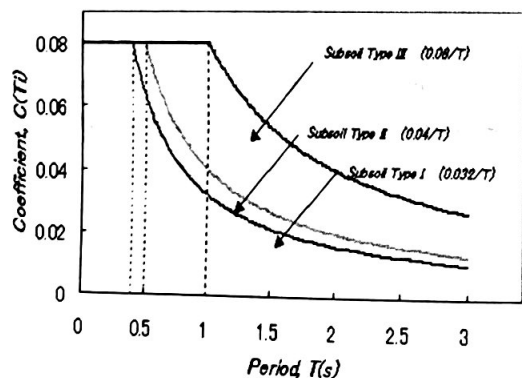
- Seismic coefficient method
- Modal Response spectrum method

Seismic coefficient method

It is applicable to regular buildings up to 40 m in height. The horizontal seismic base shear acting at the base of the structure, in the direction being considered, is, $V = C_d W_t$

where, C_d is the design horizontal seismic coefficient which shall be taken as, $C_d = CZIK$

where, C is the basic seismic coefficient which shall be determined from the figure below for appropriate soil category of site (Type I: Rock or stiff soil, Type II: Medium soil, Type III: Soft soil) using fundamental structural period determined as follows.



The fundamental period shall be approximated using,

- For framed structures with no rigid elements limiting the deflection (bare frame analysis),

$$T = 0.085 H^{3/4} \text{ for steel frames}$$

$$T = 0.06 H^{3/4} \text{ for concrete frames}$$

- For other structures,

$$T = \frac{0.09 H}{\sqrt{D}} \text{ where, } H \text{ is the height of the building in meters}$$

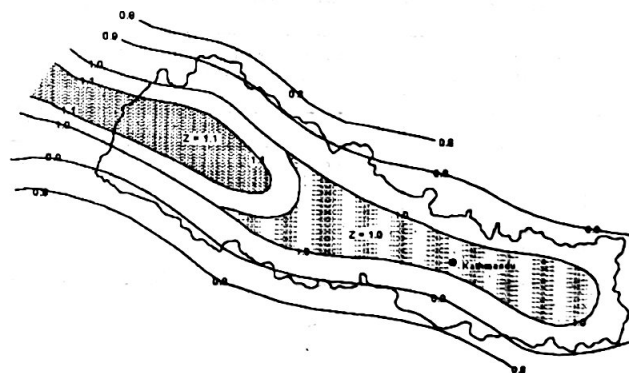
and D is the base dimension of the building at plinth level in meters along the considered direction of lateral load

The fundamental period must be checked to not vary more than 120 percent from the value obtained by the formula given below, otherwise the seismic forces need to be re-assessed.

$$T = 2\pi \sqrt{\frac{\sum w_i d_i^2}{g \sum F_i d_i}} \text{ where, } d_i \text{ may be calculated ignoring torsion}$$

Now, Z is the seismic zoning factor which shall be obtained from the figure below for appropriate location.

MUNICIPALITY	FACTOR Z	MUNICIPALITY	FACTOR Z
Shreegaur	0.93	Dharan	1.00
Bharatpur	0.99	Dipayal	1.10
Bidur	1.00	Gand	0.92
Sirendra Nagar	1.02	Ilam	0.97
Sirerthapur	0.93	Janakpur	0.89
Sirganj	0.85	Kathmandu	
Butwal	0.90	Valley Towns	1.00
Dyas	1.00	Kabendera	0.91
		Nagar	
Damak	0.96	Nepalgarh	0.91
Dhamadi	0.90	Pokhara	1.00
Dhamakuta	1.00	Tulsipur	1.00



Similarly, I is the importance factor which considers the relative importance of the building and is obtained from the table set forth.

The structural performance factor K depends upon the chosen structural type and reinforcement detailing requirements. It is extracted from the table provided. It must be noted that the structural type may be different in each of the two directions in the building and in that case, the appropriate value for K shall be selected for each direction. In the same note, when more than one structural type is used in the structure, for the direction under consideration, the structural performance factor for the element providing the majority of the seismic load resistance shall be applied provided that the elements of the other structural types have the ability to accept the resulting deformations.

Item	Structural Type	Minimum Detailing Requirements	Structural Performance Factor K
1 (a)	Ductile moment-resisting frame	Must comply with the detailing for ductility requirements of IS 4326 and for steel frames, the additional requirements of NBC 111-94	1.0
(b)	Frame as in 1 (a) with reinforced concrete shear walls	For frames : as for 1 (a). Reinforced concrete shear walls must comply with appropriate ¹ detailing for ductility requirements	1.0 ¹
2 (a)	Frame as in 1 (a) with either steel bracing members detailed for ductility or reinforced concrete infill panels	For frames : as for 1 (a). Steel bracing members must comply with the detailing for ductility requirements NBC 111-94. Reinforced concrete infill panels must comply with the detailing requirements of NBC 109-94.	1.5 ^{1,2}
(b)	Frame as in 1 (a) with masonry infills	Must comply with the detailing for ductility requirements of IS 4326	2.0 ^{1,2}
3	Diagonally-braced steel frame with ductile bracing acting in tension only	Must comply with the detailing for ductility requirements of Nepal Steel Construction Standard	2.0
4	Cable-stayed chimneys	Appropriate materials Standard	3.0
5	Structures of minimal ductility including reinforced concrete frames not covered by 1 or 2 above, and masonry bearing wall structures.	Appropriate materials Standard	4.0

Type of Building	Importance Factor I
(a) Monumental Buildings	1.5
(b) Essential facilities that should remain functional after an earthquake	1.5
Examples of these facilities would be	
Hospitals and other medical facilities	
Fire and Police stations	
Emergency vehicle shelters/garages	
Food storage structures	
Emergency relief stores	
Power stations (including standby power-generating equipment for essential facilities)	
Water works and water towers	
Radio and television facilities	
Telephone exchanges and transmission facilities	
Offices and residential quarters for senior personnel required for central and district-level rescue and relief operations (ministers, secretaries, police and army chiefs, CDO, LDO and DDC chairmen, district-level army and police chiefs)	
Places of assembly (schools, colleges, cinemas, convention halls, temples, dharmshalas)	
(c) Distribution facilities for gas or petroleum products in urban areas	2.0
(d) Structures for the support or containment of dangerous substances (such as acids, toxic substances, etc.)	2.0
(e) Other structures	1.0

Moving back to the initial equation of base shear,

W_t is the seismic weight of the whole building obtained by adding the seismic weight at each level, W_i . This W_i is the sum of dead loads and seismic live loads between the mid-heights of adjacent stories. The seismic live load shall be taken as a percentage of design live load as given below.

Design Live Load	Percentage of Design Live Load
Up to 3 kPa	25
Above 3 kPa and for vehicle garages	50
For Roofs	NIL

After computing the base shear, it is distributed at each level in the form of horizontal seismic force using the given formula.

$$F_i = V W_i h_i / \sum W_i h_i$$

where, h_i is the height from the ground to the i^{th} level or floor.

Modal response spectrum method

It is used when the structure is taller than 40 m or when the building has irregular or abrupt changes in lateral stiffness with height.

The principle behind this method is that when a building shakes during a seismic event, what we see is actually a superposition of several modes of vibration. For each mode, a specific percentage of mass of the building participates in the vibration, thus each mode has a unique fundamental time period. The code stipulates that a sufficient number of modes shall be considered to ensure at least 90 percent of the mass is participating in the direction under consideration. Now, each mode produces seismic forces in the floor levels, the calculation procedure of which is hectic and not dealt with here. These forces are combined with an accepted method, the most common being SRSS. If the obtained base shear value is lesser than 90% of the base shear from seismic coefficient approach, all combined modal effects shall be scaled up by S times where,

$$S = \frac{0.9 C_d W_e}{\sum \text{combined modal base shears in the direction under consideration}}$$

After the design earthquake forces are obtained, the effect of these forces is introduced in the design load combinations which shall be the following:

- DL + 1.3 LL + 1.25 EQ
- 0.9 DL + 1.25 EQ
- DL + 1.3 SL + 1.25 EQ

The code also has other provisions such as design eccentricity, inter-story deflection, torsion and seismic design requirements for secondary structural elements.

2. IS 1893:2002- Criteria for earthquake resistant design of structures

NBC 105 is the Nepali code equivalent of this Indian code. So, IS 1893:2002 deals with the assessment of seismic loads on various structures and earthquake resistant design of buildings. Such an assessment shall be in accordance to one of the following methods:

- Static or Seismic coefficient method
- Dynamic method

Seismic coefficient method

It is applicable to regular buildings up to 40 m in height in seismic zones IV and V, and up to 90 m in height in seismic zones II and III. It is also applicable to irregular buildings up to 12 m in height in zones IV and V and up to 40 m in height in zones II and III.

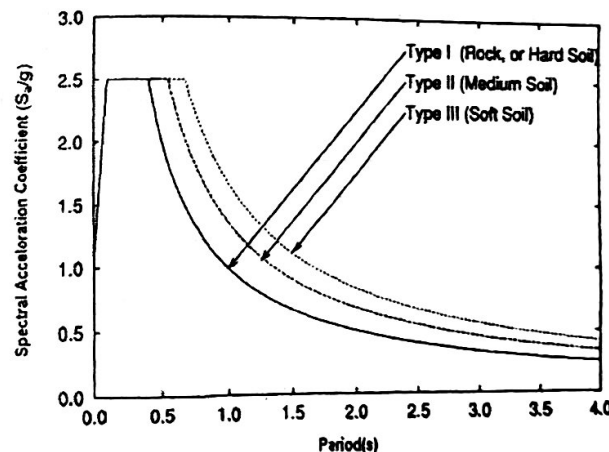
The total design lateral force or design seismic base shear acting at the base of the structure, in the direction being considered, is,

$$V_B = A_h W$$

where, A_h is the design horizontal acceleration spectrum value which shall be taken as,

$$A_h = \frac{Z I S_a}{2 R g}$$

where, S_a / g is the average response acceleration coefficient which shall be determined from the figure below for appropriate soil category of site using fundamental structural period determined as follows.



The fundamental period shall be approximated using,

- For moment resisting frame structures without brick infill panels,

$$T_a = 0.075 h^{0.75} \text{ for RC frame building}$$

$$T_a = 0.085 h^{0.75} \text{ for steel frame building}$$

where, h is height of building in meters

b) For all other structures,

$$T = \frac{0.09h}{\sqrt{d}} \text{ where, } h \text{ is the height of the building in meters}$$

and d is the base dimension of the building at plinth level in meters along the considered direction of lateral load

Now, Z is the seismic zoning factor for maximum considered earthquake which shall be obtained for appropriate location as follows.

Seismic zone	II	III	IV	V
Seismic intensity	Low	Moderate	Severe	Very severe
Z	0.10	0.16	0.24	0.36

Similarly, I is the importance factor which considers the relative importance of the building or in other words the hazardous consequences of its failure. It is taken as 1 for ordinary buildings and 1.5 for important buildings like hospitals, schools, television stations, radio stations, railway station, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations

The response reduction factor R depends upon the chosen structural type and reinforcement detailing requirements.

Sl. No.	Lateral Load Resisting System	R
Building Frame Systems		
i)	Ordinary RC moment-resisting frame (OMRF)	3.0
ii)	Special RC moment-resisting frame (SMRF)	5.0
iii)	Steel frame with	
a)	Concentric braces	4.0
b)	Eccentric braces	5.0
iv)	Steel moment resisting frame designed as per SP 6	5.0
Building with Shear Walls		
v)	Load bearing masonry wall buildings	
a)	Unreinforced	1.5
b)	Reinforced with horizontal RC bands	2.5
c)	Reinforced with horizontal RC bands and vertical bars at corners of rooms and joints of openings	3.0
vi)	Ordinary reinforced concrete shear walls	3.0
vii)	Ductile shear walls	4.0
Buildings with Dual Systems		
viii)	Ordinary shear wall with OMRF	3.0
ix)	Ordinary shear wall with SMRF	4.0
x)	Ductile shear wall with OMRF	4.5
xi)	Ductile shear wall with SMRF	5.0

Moving back to the initial equation of base shear,

W_t is the seismic weight of the whole building obtained by adding the seismic weight at each level, W_i . This W_i is the sum of dead loads and seismic live loads between the mid-heights of adjacent stories. The seismic live load shall be taken as a percentage of design live load as given below.

Design Live Load	Percentage of Design Live Load
Up to 3 kPa	25
Above 3 kPa and for vehicle garages	50
For Roofs	NIL

After computing the base shear, it is distributed at each level in the form of horizontal seismic force using the given formula.

$$Q_i = V_B W_i h_i^2 / \sum W_i h_i^2$$

where, h_i is the height from the base to the i^{th} level or floor.

Dynamic method

It is applicable to regular buildings greater than 40 m in height in seismic zones IV and V, and greater than 90 m in height in seismic zones II and III. It is also when irregular buildings exceeding 12 m in height in zones IV and V and 40 m in height in zones II and III are to be designed.

The principle behind this method is that when a building shakes during a seismic event, what we see is actually a superposition of several modes of vibration. For each mode, a specific percentage of mass of the building participates in the vibration, thus each mode has a unique fundamental time period. The code stipulates that a sufficient number of modes shall be considered to ensure at least 90 percent of the mass is participating in the direction under consideration. Now, each mode produces seismic forces in the floor levels, these forces are calculated using standard formulae somewhat similar to the base shear computation in static approach. However, the procedure is quite hectic since it involves matrix calculation for individual modes of vibration and their associated modal participation factors, which will not be dealt with, here. Moving with the flow, these forces are combined with an accepted method, which may be Complete Quadratic Combination (CQC) or Square Root of Sum of Squares (SRSS) or any other well established method.

IS 1893 allows dynamic analysis by either time history method or response spectrum method. Time history method is based on appropriate ground motion that is considered for the site whereas response spectrum is performed using design spectrum graph as shown in the static approach.

Irrespective of the method adopted for dynamic analysis, the obtained base shear value if lesser than the base shear computed from seismic coefficient approach, all combined modal effects shall be scaled up by S times where,

$$S = \frac{\text{Base shear from static approach}}{\text{Base shear from dynamic approach}}$$

After the design earthquake forces are obtained, the effect of these forces is introduced in the design load combinations which shall be the following:

- 1.5 (DL + LL)
- 1.2(DL + LL ± EQ)
- 1.5 (DL ± EQ)
- 0.9 DL ± 1.5 EQ

The code also has other provisions such as story drift deflection, torsion deformation compatibility of non-seismic members, separation between adjacent units, soft story consideration etc.

3. IS 13920 for seismic detailing

The general specifications laid down in this code are as follows:

- The design and construction of RC building shall be governed by the provision of IS 456, except as modified by the provisions of IS 13920.
- For all buildings more than 3 stories, a minimum of M20 grade of concrete shall be used. Steel reinforcement shall be of Fe 415 or less. However, high strength deformed steel bars, produced by thermo-mechanical treatment process, of grade Fe 500 or Fe 550 shall also be used.

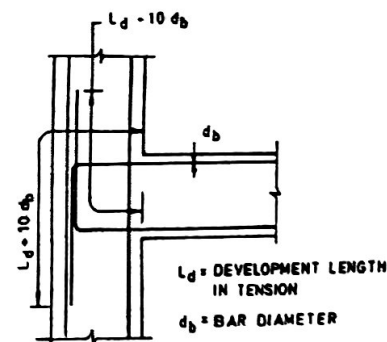
Specifications for flexural members

- The factored axial stress on flexural members under earthquake loading shall not exceed $0.1 f_{ck}$.

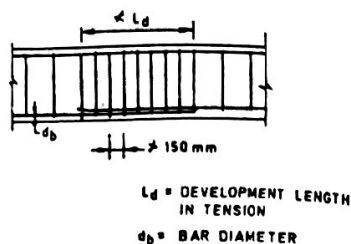
- The member shall have width greater than or equal to 200 mm, width to depth ratio greater than 0.3 and depth not more than 25% of clear span.

Longitudinal reinforcement

- There should be at least two bars running full length at the top as well as at the bottom of the beam.
- The tension steel (i.e., negative steel at the top face of the two supports and bottom face of the mid span) ratio (ρ_{mm}) on any section shall not be less than $0.24 \sqrt{\frac{f_y}{f_{ck}}}$
- The maximum steel ratio on any face at any section shall not exceed 0.025
- The positive steel at a joint (i.e., steel at the bottom face of the supports) must be half the negative steel at that section.
- The steel provided at each of the top and bottom face of the member at any section shall be at least equal to one-fourth of the maximum negative steel provided at the section of either supports.
- In an external joint, both the top and the bottom bars of the beam shall be provided with anchorage length, beyond the inner face of the column, equal to the development length in tension plus 10 times the bar diameter minus the allowance for 90 degree bend. In an internal joint, both face bars of the beam shall be taken continuously through the column.



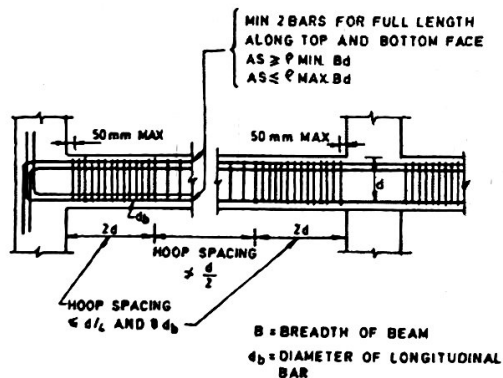
- g) The longitudinal bars shall be spliced, only if hoops are provided over the entire splice length at a spacing not exceeding 150 mm. The lap length shall not be less than the bar development length in tension. Lap splices shall not be provided (a) within a joint, (b) within a distance of $2d$ from joint face and (c) within a quarter length of the member where flexural yielding may generally occur under the effect of earthquake forces. Not more than 50% of the bars shall be spliced at one section.



- h) Use of welded splices and mechanical connections shall also be made as per IS 456.

Web reinforcement

- a) Web reinforcement shall consist of vertical hoops. A vertical hoop is a closed stirrup of minimum diameter 6 mm with a 135° hook and a 10ϕ extension (but less than 75mm) at each end.
- b) The spacing of hoops over a length of $2d$ at either end of a beam shall not exceed $d/4$ and 8 times the diameter of the smallest longitudinal bar, however it need not be less than 100 mm. The first hoop shall be at a distance not exceeding 50 mm from the joint face. Elsewhere, the beam shall have vertical hoops at a spacing not exceeding $d/2$.



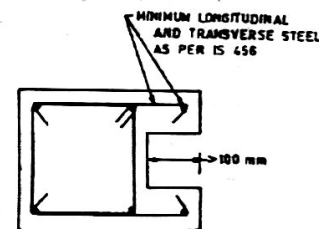
Specifications for compression members

- a) These requirements apply to frame members which have a factored axial stress in excess of $0.1 f_{ck}$ under the effect of earthquake forces.
- b) The minimum dimension of the member shall not be less than 200 mm. However, in frames which have beams with centre to centre span exceeding 5 m or columns of unsupported length exceeding 4 m, the shortest dimension of the column shall not be less than 300 mm.
- c) The ratio of the shortest cross sectional dimension to the perpendicular dimension shall preferably not be less than 0.4.

Longitudinal reinforcement

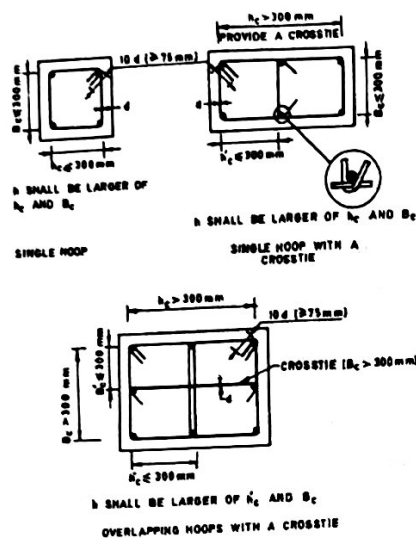
- a) Lap splices shall be provided only in the central half of the member length. It should be proportioned as a tension splice. Hoops shall be provided over the entire splice length at spacing not exceeding 150 mm center to center. Not more than 50 percent of the bars shall be spliced at one section.

- b) Any area of a column that extends more than 100 mm beyond the confined core due to architectural requirements, shall be detailed in the following manner. In case the contribution of this area to strength has been considered, then it will have the minimum longitudinal and transverse reinforcement as per this code. However, if this area has been treated as non-structural, the minimum reinforcement requirements shall be governed by IS 456.



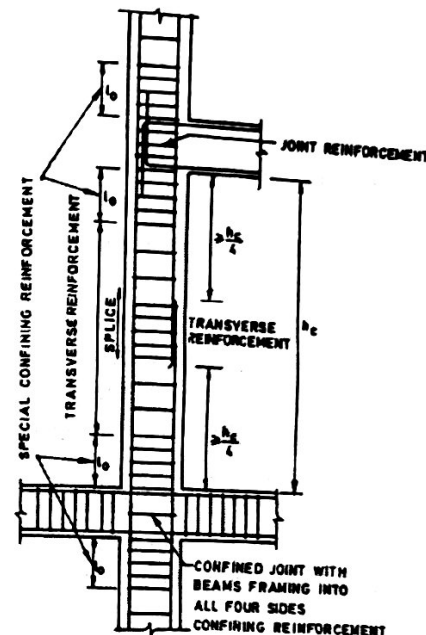
Transverse reinforcement

- a) Transverse reinforcement for circular columns shall consist of spiral or circular hoops. In rectangular columns, rectangular hoops may be used. A rectangular hoop is a closed stirrup, having a 135° hook with a 10 diameter extension (but not < 75 mm) at each end, which is embedded in the confined core.

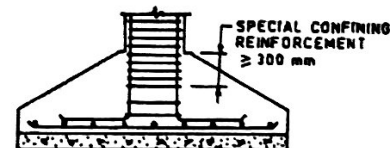


- The parallel legs of rectangular hoop shall be spaced not more than 300 mm center to center. If the length of any side of the hoop exceeds 300 mm, a crosstie shall be provided. Alternatively, a pair of overlapping hoops may be provided within the column.
- The spacing of hoops shall not exceed half the least lateral dimension of the column, except where special confining reinforcement is provided.
- Special confining reinforcement shall be provided over a length l_o from each joint face, towards mid span, and on either side of any section, where flexural yielding may occur under the effect of earthquake forces. The length ' l_o ' shall not be less than (a) larger lateral dimension of the member at the section where yielding occurs, (b) $1/6$ of clear span of the member, and (c) 450 mm. When a column terminates into a footing or mat, special confining reinforcement shall extend at least 300 mm into the footing or mat. When the calculated point of contra-flexure, under the effect of gravity and earthquake loads, is not within the middle half of the member clear height, special confining reinforcement shall be provided over the full height of the column. Columns supporting reactions from discontinued stiff members, such as walls, shall be provided with special confining reinforcement over their full height. Special confining

reinforcement shall also be provided over the full height of a column which has significant variation in stiffness along its height. This variation in stiffness may result due to the presence of bracing, a mezzanine floor or a R.C.C. wall on either side of the column that extends only over a part of the column height.



COLUMN AND JOINT DETAILING



PROVISION OF SPECIAL CONFINING REINFORCEMENT IN FOOTINGS

The spacing of hoops used as special confining reinforcement shall not exceed $1/4$ of minimum member dimension but need not be less than 75 mm nor more than 100 mm.

Specifications for shear walls

- The thickness of any part of the wall shall preferably not be less than 150 mm.

- b) The effective flange width, to be used in the design of flanged wall sections, shall be assumed to extend beyond the face of the web for a distance which shall be the smaller of (a) half the distance to an adjacent shear wall web, and (b) $1/10^{\text{th}}$ of the total wall height.
- c) Shear walls shall be provided with reinforcement in the longitudinal and transverse directions in the plane of the wall. The minimum reinforcement ratio shall be 0.0025 of the gross area in each direction. This reinforcement shall be distributed uniformly across the cross section of the wall.
- d) If the factored shear stress in the wall exceeds 0.25 or if the wall thickness exceeds 200 mm, reinforcement shall be provided in two curtains, each having bars running in the longitudinal and transverse directions in the plane of the wall.
- e) The diameter of the bars to be used in any part of the wall shall not exceed $1/10^{\text{th}}$ of the thickness of that part.
- f) The maximum spacing of reinforcement in either direction shall not exceed the smaller of $l_w/5$, $3 t_w$, and 450 mm; where l_w is the horizontal length of the wall, and t_w is the thickness of the wall web.
- g) The shear strength of a wall with openings should be checked along critical planes that pass through openings. Reinforcement shall be provided along the edges of openings in walls. The area of the vertical and horizontal bars should be such as to equal that of the respective interrupted bars. The vertical bars should extend for the full story height. The horizontal bars should be provided with development length in tension beyond the sides of the opening.
- h) Boundary elements are portions along the wall edges that are strengthened by longitudinal and transverse reinforcement. Though they may have the same thickness as that of the wall web, it is advantageous to provide them with greater thickness. Where the extreme fiber compressive stress in the wall due to factored gravity loads plus factored earthquake force exceeds $0.2f_{ck}$, boundary elements shall be provided along the vertical boundaries of walls. The boundary elements may be discontinued where the calculated compressive stress becomes less than $0.15f_{ck}$. The compressive stress shall be calculated using a linearly elastic model and gross section properties. A boundary element shall have adequate axial load carrying

capacity, assuming short column action, so as to enable it to carry an axial compression equal to the sum of factored gravity load on it and the additional compressive load induced by the seismic force. If the gravity load adds to the strength of the wall, its load factor shall be taken as 0.8. The percentage of vertical reinforcement in the boundary elements shall not be less than 0.8 percent, nor greater than 6 percent. In order to avoid congestion, the practical upper limit would be 4 percent. Boundary elements, where required, shall be provided throughout their height, with special confining reinforcement.

4. IS 4326: Earthquake resistant design and construction of buildings

This standard deals with the selection of materials, special features of design and construction for earthquake resistant buildings including masonry construction using rectangular masonry units, timber construction and buildings with prefabricated flooring / roofing elements. The general recommendations of this code in the construction of earthquake resistant buildings are:

a) Lightness

Since the earthquake force is a function of mass, the building shall be as light as possible consistent with structural safety and functional requirements.

b) Continuity of construction

The parts of the building should be tied together in such a manner that the building acts as one unit. Concrete slabs shall be rigidly connected or integrally cast with the support beams. Additions and alterations of the structures shall be accompanied by the provision of separation between the new and existing structures unless positive measures are taken to establish continuity between the existing and the new construction.

c) Projecting and suspended parts

Projecting parts shall be avoided as far as possible. If the projecting parts cannot be avoided, they shall be properly reinforced and firmly tied to the main structure, and their design shall be in accordance with IS 1893:2002. Ceiling plaster shall preferably be avoided. When it is unavoidable, the plaster shall be as thin as possible. Suspended ceiling shall be avoided as far as possible. Where provided, they shall be light, adequately framed and secured.

d) Building configuration

To minimize torsion and stress concentration, the building must have simple rectangular plan and be symmetrical both with respect to mass and rigidity so that the center of mass and rigidity of the building coincide with each other. If symmetry of the structure is not possible, provision shall be made for torsional and other effects due to earthquake forces in the structural design. Buildings having plans with shapes like L, T, E, Y shall preferably be separated into rectangular parts by providing separation sections at appropriate locations. Such separation is however not required if the projection does not exceed 15 to 20 percent of the total dimension of the building in that direction.

e) Strength in various directions

The structure shall be designed to have adequate strength against earthquake effects along both the horizontal axes. The design shall also be safe considering the reversible nature of earthquake forces.

f) Foundations

The structure shall not be founded on such loose soils which will subside or liquefy during an earthquake, resulting in large differential settlements.

g) Ductility

The main structural elements and their connection shall be designed to have a ductile failure. This will enable the structure to absorb energy during earthquakes to avoid sudden collapse of the structure. Providing reinforcing steel in masonry at critical sections, as per details provided in the standard, will not only increase strength and stability but also ductility.

h) Damage to non-structural parts

Suitable details shall be worked out to connect the non-structural parts with the structural framing so that the deformation of the structural frame leads to minimum damage of the non-structural elements.

i) Fire safety

Fire frequently follows an earthquake and therefore, building shall be constructed to make them fire resistant.



Old Questions

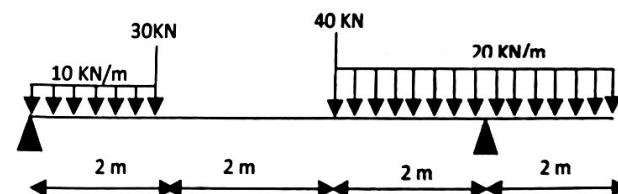
Year 2067/68

Section A

- 1) Sketch and explain English bond brick wall in plan and elevation showing the use of three-quarter bats, queen closers, header and stretcher, face and frog of the bricks, beds and vertical joints. Also draw king closer and beveled closers.
- 2) a) What do you understand by 'Natural Bed of stone'? Why a stone should be set in a structure upon this bed? Show correct positions of natural bed in case of cornice, arch and corner stone.
b) Name the stones you select for following works:
 - Random rubble masonry
 - Coarse aggregate for RCC
 - Face work of wall
 - For construction of bridge
 - For packing pathways
 - For fire-proofing purpose
- 3) Compare how the problem of damp proofing differs from problems of water proofing. Describe with a sketch a method of internal water proofing for a basement room.

Section -B

- 4) For the beam shown in figure below draw the shear force and bending moment diagram using section method. Locate the point of contra flexure if any.



- 5) The drawing room of a residential building is 8m X 15m, show by rough sketch the layout plan of RCC beams and slab. The spacing of beams shall make the cost of slab minimum. It is not necessary to show design calculation. Also draw the layout of reinforcement of beam and slab, including approximate spacing of shear reinforcement of the beam.

Section C

- 6) Describe in brief what you understand by master plan, structure plans, local area plan and site plan.
- 7) Compare the planning of the traditional urban settlements of Kathmandu with its contemporary expansion in terms of mitigation of disaster related to earthquakes.
- 8) What are the main problems of housing in rural Nepal? Discuss the issue with particular reference to resettlement activities in the Terai.

Section D

- 9) The contribution of Le-Corbusier in the evolution of world contemporary architecture is found to be always revolutionary. Explain with the help of sketches that his ideas are translated into reality in High Court Building at Chandigarh.
- 10) What is context based design? How is this applied in building design and bye-laws in the heritage cores of the traditional towns of Kathmandu?

Year 2068/69

Section A

- 1) What do you understand by pre-fabrication? State the advantages of pre-cast RCC construction and explain why it has not been popular in Nepal.
- 2) Explain the different methods of water-proofing in buildings. Also give relative advantages of each type.
- 3) a) Explain foundations
b) Explain the design of a simple stepped strip foundation. What are some of the common problems in this type of foundation?

Section B

- 4) What are the various loads that should be taken into account when designing a RCC structure and why? What are the materials commonly used for formwork for RCC structures in Nepal?
- 5) Design a two way slab for a room having clear dimensions 5m X 4m. The superimposed load is 200kg/m². Use M15 mix and assume that the corners of the slabs are not held down.

Section C

- 6) What do you mean by EIA? Elaborate on need and methodology of EIA. In which year EIA was introduced in Nepal?
- 7) Kathmandu city is losing its physical and cultural heritage day by day. In your opinion, what strategies should be followed to conserve the Kathmandu valley?
- 8) Describe the types of land development that is commonly applied in Nepal. Under what legislation the land development schemes can be implemented? Describe briefly salient features of a land pooling scheme.

Section D

- 9) Explain why the vernacular architecture of Nepal is different from place to place. Discuss the issue with reference to topography, ethnicity, culture geology and vegetation.
- 10) How does contemporary architecture effect the ecological systems of the region?

Year 2070/71

Section A

- 1) What do you understand by the term Formwork? What are the essential requirements of a good formwork? Describe the steps to be taken to effect economy in the expenditure on formwork?
- 2) Explain in brief, construction sequences for retrofitting a) Wall and Jack-arch floor of a load bearing Rana Durbar and b) Sloped RCC slab of a residential building over 450 mm thick random rubble masonry wall. Also, suggest improvement in low cost construction practice based on explanation of proposed retrofitting.

Section B

- 3) Write an essay on 'Availability of building material in Nepal'. (Qualify technological aspects and prevailing building practices. Present recommendations for "forward looking technologies" for urban and rural building techniques and improvement of quality of the building materials).
- 4) Explain characteristics of Earthquake Resistant Buildings. How Mandatory Rules of Thumb helps to design non-engineered buildings?
- 5) What are the assumptions and requirements in the design of RCC footing? Compute the footing required for a square column 40 cm X 40 cm carrying a load of 100,000 kg if the bearing capacity of soil is 20 tonnes/m².

Section C

- 6) Describe the housing situation in Kathmandu valley as its supply changes over from owner built to private developer led. Comment on role and effectiveness of the Apartments Act in ensuring the proper safety and security of services and housing environment both inside and around the housing estates.
- 7) Describe the various methods of land development in Nepal.
- 8) What are the positive roles of municipality in urban development? Explain in relation to available planning regulations and use of building byelaws in urban context.

Section D

- 9) "Art and artifact of the Kathmandu valley are reflected in monuments and dwellings which became basis for the exploration of architecture in the context". Explain with your agreement and disagreement with reasons.
- 10) State briefly the main problems in standardization of government building in Nepal.

Year 2071-72**Section A**

- 1) What are the sources of dampness in buildings and its negative effects? Sketch a section to show internal waterproofing of basement using tar felt.
- 2) Describe with neat sketches of the following:
 - a) Framed and paneled doors
 - b) Sky light
- 3) Compare briefly between stone masonry and brick masonry.

Section B

- 4) Draw S.F. and B.M. diagram for a cantilever of 4.0m carrying a uniformly varying load of intensity zero at free end to 2000 kg/m at support.
- 5) Describe, with sketches, the general requirements for earthquake resistant construction in terms of (a) shape and proportion of plan (b) size and placing of opening in wall (c) vertical reinforcements and horizontal band ties for masonry walls.

Section C

- 6) Mention with examples hierarchy of urban settlements in Nepal.
- 7) Apartment housings are drawing attention in Nepal, describe your opinions on the merits and demerits of apartments, also illustrate norms for apartments in inside and outside of ring road in Kathmandu.
- 8) Why is it necessary to involve private sector in the housing development project of Nepal. Suggest ways for enhancing public private partnership in housing and urban development of Nepal.

Section D

- 9) What are the matters to keep in mind while designing and building a house? Describe briefly about each matters.
- 10) Which building has been designed by LOUIS KAHN in Kathmandu? What are the main features of that building?

Year 2072-73**Section A**

- 1) Define shoring and describe its types with neat and clean sketches.
- 2) Draw a typical wall section of an earthquake resistant single storey building with load bearing walls.
- 3) Write briefly the bonds in brickwork and describe English bond with sketches of alternate layers and isometric view.

Section B

- 4) Describe singly reinforced section and doubly reinforced section of concrete structure, particular for RCC beam section. State the main use of both sections and exemplify of both sections with sketches emphasizing on earthquake resistant need.
- 5) Define Hook's law. Calculate shear force and bending moment of the simply supported beam with span 4m c/c and point load of 10 KN at the centre of the span. Also draw the shear force and bending moment diagram.

Section C

- 6) What are the different kinds of urban housing? Describe in detail about "Site and services".
- 7) What do you understand by the term "land use planning"? Write the importance of land use planning in urban development. Which agencies are involved for urban development in Nepal?
- 8) What is a periodic plan of a municipality? How can municipality play its roles in urban development of Nepal?

Section D

- 9) Write on vernacular architecture of Nepal in general and Kathmandu in particular.
- 10) What do you understand by traditional architecture in Nepal? Illustrate three architectural landmarks in Nepal.

Year 2073-74**Section A**

- 1) What are the pre-fabrication materials commonly used now for walls and roofings of different buildings and explain briefly. Explain why prefab materials in building construction has been popular after earthquake, 2072?
- 2) How do you define a load bearing wall in a building? Draw a neat, well illustrated section of load-bearing wall showing its foundation, sill, lintel band, window section and parapet wall for a one-storied building.
- 3) How do you define mortar in building construction? Describe briefly about cement / sand mortar. Write down the mixing proportion of cement / sand mortar for foundation works, ordinary masonry works, pointing works and boundary wall construction works.

Section B

- 4) Design a R.C.C. footing for a wall carrying 200 KN per running meter at foundation level on loose soil having a safe bearing capacity of 50 KN per square meter.
- 5) a) Describe singly reinforced and doubly reinforced concrete beam. Draw sketches of both beams.
b) Define column is a RCC structure. Differentiate between short column and long column.

Section C

- 6) What is a periodic plan of a Municipality? Explain how it is prepared?
- 7) Describe briefly with the sketches base map, master plan, land use plan and setback.
- 8) Explain what is land development? Explain the steps in sequences of land development under land pooling scheme.

Section D

- 9) Draw the construction of roof of traditional buildings of Kathmandu Valley.
- 10) Compare broadly on the designing principles between Frank Lloyd Wright and Mies-Vanda Rohe.

लोक सेवा आयोग

नेपाल इन्जिनियरिङ सेवा, सिभिल समूह, बिल्डिङ एण्ड आर्किटेक्ट उपसमूहको राजपत्राङ्कित तृतीय श्रेणी पदका खुला र आन्तरिक प्रतियोगितात्मक लिखित परीक्षाको

विषयगत नमूना प्रश्नहरू [SAMPLE QUESTIONS]

1. Mention the different types of the stone walls that are used in a building. Describe their suitability in foundation and superstructure.
2. Describe the different bonds that are used in brick walls. Write their usefulness compared to hollow concrete blocks.
3. Write about the qualities of good sand used for building. Discuss the usefulness of the lime and cement sand mortar.
4. A modern building has to be painted in different colors. Describe which paints will you use in the exterior and the interior. Write about the ways of using the paint in the exterior wall.
5. What are the effects of dampness in buildings? Write how the damp proofing of a basement is carried out.
6. Differentiate between the panelled and the flush doors. Draw a section through a window having openable and fixed shutters.
7. Differentiate between a single, double and triple roofs. A room 4.5 meter wide has to be constructed using timber roof. Draw a sketch of its plan, elevation and section giving the dimensions of all the members.
8. What are the requirements of a good floor? Draw a sketch of a solid ground floor using concrete for a residence.
9. What do you understand by temporary constructions? Differentiate between shoring and underpinning. Draw a sketch of a building wall being underpinned with shoring provided to it.
10. What are the different elements of a building? Draw a wall section right from the foundation to the roof of a building. Give the names and the dimensions of all the elements such as foundation, lintel, etc.



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